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GUGGENHEIM AERONAUTICAL LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

# EXPERIMENTAL INVESTIGATION OF TEMPERATURE AND VELOCITY DISTRIBUTION ABOUT A ROCKET JET

Thesis by

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# EXPERIMENTAL INVESTIGATION OF TEMPERATURE AND VELOCITY DISTRIBUTION ABOUT A ROCKET JET

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Lt. C. R. Whitmore, U.S.N.

In Partial Fulfillment of the
Requirements for the Professional Degree
in Aeronautical Engineering

California Institute of Technology

Pasadena, California

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The author is indebted to Mr. Stanley S. Corrsin for his helpful suggestions concerning equipment which could be used for the investigation.

The author wishes to express his appreciation for the cooperation and suggestions of Mr. Anthony Briglio and the members of the pit "F" test crew.

# SUMMARY

The purpose of the investigation was to determine the temperature distribution and velocity profile surrounding the wake of a 1500 pound thrust liquid rocket motor. The temperature measurements were restricted to those 500°F and below. The velocities measured were in the region in which the temperature measurements were made.

The region in which the temperatures exceeded 500°F was found to be included within a solid angle of ten degrees. The high temperature region was found to be larger than the high velocity region.

The investigation was carried out during the academic year 1946-1947 at GALCIT Jet Propulsion Laboratory under the supervision of Dr. Robert H. Boden.

# INTRODUCTION

The jet of gases from a de Laval nozzle has been extensively studied by a number of investigators. These studies were primarily limited to the shock wave characteristics in the supersonic flow. Optical methods have been developed to show the variation of density in the jet. However, little experimental work has been done to determine the velocity, pressure, and temperature in the jet and in the regions surrounding the high velocity gases.

The object of this investigation was to measure the velocity and temperature distribution in the region surrounding the high velocity luminous gases.

The measurements were carried out at GALCIT in the Jet Propulsion Laboratory during the academic year 1946-47 under the supervision of Dr. Robert Boden.

## EQUIPMENT

The liquid rockets which were run for performance data with various fuel specifications were of the regeneratively cooled type developing a 1500 pound thrust. The rocket motors were all mounted on the same thrust carriage and the structure of the pit surrounding the rockets remained essentially the same for all of the runs. The rocket motors were mounted horizontally as shown in Fig. 1. Figs. 1 and 2 show the irregular nature of the area into which the rocket was fired.

The radiation thermocouples which were used to make the temperature survey were of the iron-constantan type. Instructions and a schematic drawing of the type used may be found in Fig. 3. The thermocouples were used in connection with a Brown Potentiometer which had 15 outlets. The potentiometer could record the 15 different temperatures at a rate of one a second if the temperature at each thermocouple were constant. Fig. 5 is a photograph of this Brown Potentiometer. A rack made of pipe and angle iron was built to hold the thermocouples in position as shown in Fig. 5.

To reduce the effect of radiation, a shield was built to protect a thermocouple from the flame of hot gases. Fig. 6 is a schematic representation of the shield used to produce this effect.

A Leeds and Northrop portable optical Pyrometer, No. 8622, was used to determine the flame temperature of the luminous flame. The circuit of this pyrometer appears in Fig. 7.

A stagnation temperature probe which doubled as a shielded thermocouple was mounted on the rack as shown in Fig. 5. Fig. 8 is a photostatic copy of the production drawing for the stagnation probe.

The Prandtl Pitot tube was selected as best suited for the velocity survey because of its yaw characteristics as shown in Fig. 9. Fig. 10a and Fig. 10b are copies of the production drawings for the Prandtl tube. Because of the high temperatures to which the tubes were to be subjected, the joints were all silver soldered. The Pitot tubes were mounted upon the thermocouple rack six inches apart, (Fig. 5). One-quarter inch copper tubing was used to connect the Pitot tubes with the tubes of the multiple manometer board.

The multiple manometer board (Fig. 11) consisted of 12 "U" tubes half filled with alcohol. The alcohol was dyed red to improve its photographic characteristics. The board was mounted upon a frame of angle iron which could be bolted in three tilting positions (90°, 30°, and 14.5°). To record the manometer tube displacements, a 35 mm. movie camera was mounted on the manometer frame. Two reflector type photo flood lamps, mounted as shown in Fig. 11, provided the illumination.

To measure the velocities close to the motor within the firing pit, a remote control variable position Prandtl tube was built (Fig. 12). A small synchro was placed inside of a metal box with a shaft protruding through the top to which the Prandtl tube was mounted (Fig. 13). The control synchro and power source for the variable position Pitot tube can be seen in Fig. 14. This control station was inside the observation room of the pit. Fig. 15 is the electrical circuit for the control of the variable position Pitot. The pressures from this remote controlled Pitot tube were measured with the small inclined manometer, Fig. 16.

The luminous portion of the jet was photographed with an Eastman high speed 16 mm. movie camera. The camera was capable of taking 3,000 frames a second and was run at top speed for these photographs. Two portions of the flame were studied; (1) the region just aft of the nozzle; (2) the region in which the luminous flame ends.

## PROCEDURE

The rocket motors were run primarily for performance information. The temperature and velocity survey of this report was added after the performance series had been started.

(1) An initial survey to determine the suitability of an iron-constantan thermocouple was made during test runs Nos. 18, 19, 20, 21, 22, 24, 25, 26, 27 and 29. The lag in temperature response was measured during these runs.

(2) An attempt was made to protect the thermocouple from the direct radiation of the flame and to determine the effectiveness of a shield during run Nos. 28, 29, 30, 31, 32, 33, 34, and 35.

(3) A Prandtl Pitot-static tube was placed in the field to determine the possibility of using that tube for the velocity survey during runs Nos. 37 and 38.

The initial runs demonstrated that the instruments selected could be used to obtain the objectives. A rack was made upon which 11 thermocouples and 12 Pitot tubes were mounted. The Brown Potentiometer was available in the pit and the inclined manometer board was built so that velocities over a wide range could be determined.

The rack was placed perpendicular to the longitudinal axis of the motor at five stations behind the motor. The five stations were 26.5, 24.5, 22, 19 and 16 feet aft of the motor nozzle. The rack was so oriented for runs 73 to 93 inclusive. For runs 95 to 98 the rack was placed at a 37° angle so that the direction of the velocity could be determined. The temperature survey within six feet of the motor was completed by placing the rack parallel with the longitudinal axis of the motor during runs 99 and 100.

The stagnation temperature was determined by placing the stagnation probe on the rack for runs 95 to 98 inclusive.

The remote control Pitot tube was placed inside the pit close to the motor to measure the velocity profile there during runs 84 to 98 inclusive.

The investigation was extended to the flame characteristics with the use of the Leeds and Northrop Optical Pyrometer and an Eastman high speed movie camera. The optical pyrometer was held 10 feet aft of the motor and 10 feet from the axis of the flame. From this position the pyrometer was sighted upon the flame six feet aft of the nozzle. The high speed camera was set up to take kodachrome pictures of the exit of the motor during run No. 84. Black and white pictures of the end of the flame were taken during run No. 85. The camera was 10 feet from the flame during run No.84 and 45 feet from the flame during run No. 85.

## RESULTS AND DISCUSSION

(1) A blackened thermocouple when exposed to a high temperature requires time to reach that temperature. Fig. 17 is the response of the thermocouples which were used in this investigation. The data for this curve was obtained from runs Nos. 19 to 23 as shown in Table I(a) to I(j). It was realized that the response of the thermocouple was faster when the change in temperature was small compared with the ambient air temperature.

(2) The shield about the thermocouple reduced the temperature rise and also produced a much slower temperature rise as is indicated in Fig. 18.

(3) The temperature surveys taken 26.5, 24.5, 22, 19 and 16 feet aft of the motor are plotted, Figs. 19a to 23a and 24a and b, as temperature rise versus radial distance from the center line of the axis of the flame. The rise in temperature was in each case corrected for time lag by the use of the thermocouple Response Curve, Fig. 17. The data is quite consistant considering the variations caused by winds and that the mixture ratio was seldom repeated. However, the temperatures measured by the thermocouples are not necessarily the air temperatures, since the air is relatively transparent to radiation. The thermocouples reached equilibrium after sixty seconds which indicates that they were losing as much energy via conduction along the leads, convection to the air, and the radiation losses as they were receiving via radiation. Some of the temperatures were taken in the mixing region of the jet gases and ambient air. The location of this mixing region was not determined in this investigation.

(4) The flame temperatures six feet aft of the nozzle as measured by the optical pyrometer, were 33[illegible]0°F, 3260°F, and 3300°F. These temperatures are approximately 600° above the theoretical exit temperatures. This may be explained by the after burning of the exhaust gases. The emissivity of the flame was taken to be unity because it consists mainly of glowing carbon particles. The pyrometer was hand held at a distance of ten feet aft of the motor and ten feet from the center line of the exhaust flame. A slight burning sensation was felt by the observer on the face and arms which were exposed to the flame.

(5) The velocity measurements were made with the assumption that the flow was parallel with the ground at the level of the motor. This assumption was not checked and may have been erroneous. The velocity versus distance from the center line of the exhaust jet may be found in Figs. 19b to 23b. A plot of the velocity profile showing direction velocity and streamlines may be seen in Figs. 25 and 27.

(6) The characteristic of the first shock wave aft of the motor in the jet was recorded on a Kodachrome film by the Eastman high speed camera during run No. 84. It was not possible to measure the velocity of the exhaust gases from this film. A higher speed camera with a larger field is necessary. The average velocity of the end of the luminous gases which was measured from the black and white film taken during run No. 85, was determined to be 2300 ft/sec. Since the flow was subsonic at this distance from the motor, this would require an exhaust temperature of 2110°F at least, if the of the gases was 1.2. The velocity was therefore considered to be a reasonable one.

## CONCLUSIONS AND RECOMMENDATIONS

(1) The temperatures surrounding the jet of a 1500 pound thrust liquid rocket, as measured by a blackened thermocouple, are surprisingly low. The high temperature region gradually expands as the distance aft of the motor is increased. At 26.5 feet aft of the motor, the temperature can be expected to be 500°F higher than ambient at a distance of 25 inches from the center line of the motor. At a distance of four feet aft of the nozzle, the temperature rise can be expected to be 500° when only 12 inches from the center line of the flame. However, a considerable amount of heat is conducted away by the thermocouple leads. Therefore, before placing equipment as closely as these temperatures indicate as safe, it would be necessary to determine the heat losses of the equipment to be expected from conduction, radiation, and convection.

(2) The velocity survey was rather sketchy, but does show that the induced velocities are quite small and of the order of 50 ft/sec. The velocities were appreciable (over 100 ft/sec.) in the region in which mixing was expected. It was found that the high temperature regions were larger than the high velocity region, as was found by other investigators dealing with small hot jets.

The induced velocities might be successfully measured with the use of small smoke sources placed throughout the region of interest and the paths of the smoke recorded by a movie camera. A rack of Pitot tubes could be made so that each tube could be pivoted during the run. This could be accomplished very nicely by electrical or mechanical linkages.

The survey should be extended to include the luminous region of the exhaust gases. A spectogram of the flame would be desirable. The optical pyrometer could be successfully employed to determine the flame temperatures if the emissivity of the flame were determined.

The ultra-high speed camera may be the best method to determine the velocities of the hot exhaust gases.

## TABLE Ia

## TEMPERATURE SURVEY

Run #18 Duration of Run 45.8 sec. Motor M-272

**Fuel** FUOH

Oxidizer WFNA Mixture Ratio 1.35

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 21" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 52 | 0 | 52 |
| 6 | 86 | 7 | 132 |
| 37 | 106 | 38 | 152 |
| 53 | 82 | 54 | 122 |
| 70 | 74 | 71 | 109 |

## TABLE Ib

## TEMPERATURE SURVEY

Run #19 Duration of Run 59.6 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 1.26

| Thermocouple #2 | | Thermocouple # 3 | |
|---|---|---|---|
| Dist. aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. aft of Motor 48"<br>Dist. from ℄ of Motor 15" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 53 | 0 | 53 |
| 14 | 74 | 15 | 142 |
| 35 | 82 | 37 | 166 |
| 58 | 85 | 59 | 169 |

## TABLE Ic

## TEMPERATURE SURVEY

Run #20 Duration of Run 45 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 1.96

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. aft of Motor 48"<br>Dist. from ℄ of Motor 12" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 56 | 0 | 56 |
| 30 | 69 | 6 | 386 |
| | | 33 | 426 |

## TABLE Id

## TEMPERATURE SURVEY

Run #21 Duration of Run 44.9 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 1.91

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 12" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 57 | 0 | 57 |
| 18 | 70 | 30 | 494 |

## TABLE I(f)

## TEMPERATURE SURVEY

Run #23 Duration of Run 45 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 2.30

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 12" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 55 | 0 | 56 |
| 15 | 87 | 16 | 226 |
| 40 | 93 | 42 | 240 |

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## TABLE I(g)

## TEMPERATURE SURVEY

Run #24 Duration of Run 45.1 sec. Motor M-272

Fuel FUOH Oxidizer WFNA Mixture Ratio 2.30

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 120"<br>Dist. from ℄ of Motor 30" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 73 | 0 | 74 |
| 12 | 91 | 14 | 151 |
| 37 | 102 | 39 | 173 |

## TABLE I(h)

## TEMPERATURE SURVEY

Run #25 Duration of Run 45.1 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 2.26

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 120"<br>Dist. from ℄ of Motor 30" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 64 | 0 | 88 |
| 1 | 65 | 2 | 130 |
| 31 | 99 | 32 | 148 |

## TABLE I(i)

## TEMPERATURE SURVEY

Run #26 Duration of Run 21 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 2.39

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 120"<br>Dist. from ℄ of Motor 18" | |
| Time Sec. | Temperature °F | Time Sec. | Temperature °F |
| 0 | 74 | 0 | 79 |
| 11 | 90 | 15 | 489 |

# TABLE I(j)

## TEMPERATURE SURVEY

Run #27 Duration of Run 45.1 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 2.20

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 120"<br>Dist. from ℄ of Motor 19" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 67 | 0 | 67 |
| 30 | 90 | 35 | 500 |

## TABLE I(k)

## TEMPERATURE SURVEY

Run #35 Duration of Run 44.8 sec. Motor M-272

Fuel FUOH

Oxidizer 95% WFNA & 5% $H_2O$ Mixture Ratio 2.15

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48" | | Dist. Aft of Motor 120" | |
| Dist. from ℄ of Motor 67" | | Dist. from ℄ of Motor 13" | |
| Time Sec. | Temperature °F | Time Sec. | Temperature °F |
| 0 | 66 | 0 | 74 |
| 29 | 96 | 1 | 266 |
| | | 30 | 500 |

## TABLE I(b)

## TEMPERATURE SURVEY

Run #36 Duration of Run 44.8 sec. Motor M-272

Fuel FUOH

Oxidizer 95% WFNA & 5% $H_2O$ Mixture Ratio 2.05

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48" | | Dist. Aft of Motor 120" | |
| Dist. from ₵ of Motor 67" | | Dist. from ₵ of Motor 22" | |
| Time<br>Sec. | Temperature<br>°F | Time<br>Sec. | Temperature<br>°F |
| 0 | 66 | 0 | 72 |
| 11 | 84 | 14 | 166 |
| 34 | 98 | 35 | 182 |

## TABLE I(m)

## TEMPERATURE SURVEY

Run #38 Duration of Run 59 sec. Motor M-272

Fuel FUOH

Oxidizer 95% WFNA & 5% $H_2O$ Mixture Ratio 2.20

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 15" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 61 | 0 | 62 |
| 9 | 76 | 10 | 126 |
| 32 | 86 | 33 | 141 |
| 55 | 93 | 59 | 158 |

## TABLE I([illegible])

## TEMPERATURE SURVEY

Run #39 Duration of Run 45 sec. Motor M-272

Fuel FUOH

Oxidizer 95% WFNA 5% $H_2O$ Mixture Ratio 2.32

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 300" | | Dist. Aft of Motor 15"<br>Dist. from ℄ of Motor 36" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 56 | 0 | 64 |
| 32 | 58 | 10 | 145 |
| | | 38 | 169 |

## TABLE II(a)

## TEMPERATURE SURVEY

Run #28    Duration of Run 45.4 sec.    Motor M-272

Fuel FUOH

Oxidizer WFNA    Mixture Ratio 2.56

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ¢ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ¢ of Motor 24" | |
| Time Sec. | Temperature °F | Time Sec. | Temperature °F |
| 0 | 67 | 0 | 67 |
| 12 | 79 | 13 | 90 |
| 40 | 89 | 41 | 130 |
| 65 | 79 | 66 | 126 |
| | | 82 | 120 |

## TABLE II(b)

## TEMPERATURE SURVEY

Run #29    Duration of Run 45 sec.    Motor M-272

Fuel FUOH

Oxidizer WFNA    Mixture Ratio 2.53

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ₵ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ₵ of Motor 24" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 66 | 0 | 66 |
| 22 | 82 | 83 | 102 |
| 45 | 86 | 46 | 122 |
| | | 110 | 119 |

## TABLE II(c)

## TEMPERATURE SURVEY

Run #30　Duration of Run 45.2 sec.　Motor M-272

Fuel FUOH

Oxidizer WFNA　Mixture Ratio 3.03

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 22" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 62 | 0 | 62 |
| 15 | 71 | 16 | 82 |
| 40 | 74 | 41 | 105 |
| | | 65 | 104 |
| | | 82 | 102 |

## TABLE II(d)

## TEMPERATURE SURVEY

Run #31 Duration of Run 45.2 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 3.11

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 300"<br>Dist. from ℄ of Motor 36" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 57 | 0 | 59 |
| 26 | 63 | 27 | 90 |
| | | 57 | 97 |
| | | 74 | 96 |

## TABLE II(e)

## TEMPERATURE SURVEY

Run #32 Duration of Run 45.6 sec. Motor M-272

Fuel FUOH

Oxidizer WFNA Mixture Ratio 3.10

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor | 48" | Dist. Aft of Motor | 48" |
| Dist. from ℄ of Motor | 67" | Dist. from ℄ of Motor | 22" |
| Time Sec. | Temperature °F | Time Sec. | Temperature °F |
| 0 | 64 | 0 | 64 |
| 23 | 75 | 24 | 86 |
| 55 | 73 | 56 | 105 |
| 73 | 70 | 74 | 102 |

## TABLE II(f)

## TEMPERATURE SURVEY

Run #33    Duration of Run 45 sec.    Motor M-272

Fuel FUOH

Oxidizer 95% WFNA & 5% $H_2O$    Mixture Ratio 3.10

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 22" | |
| Time Sec. | Temperature °F | Time Sec. | Temperature °F |
| 0 | 66 | 0 | 68 |
| 13 | 90 | 14 | 76 |
| 38 | 104 | 39 | 96 |
| 62 | 88 | 63 | 105 |

## TABLE II(g)

## TEMPERATURE SURVEY

Run #34 Duration of Run 45 sec. Motor M-272

Fuel FUOH

Oxidizer 95% WFNA & 5% $H_2O$ Mixture Ratio 1.73

| Thermocouple #2 | | Thermocouple #3 | |
|---|---|---|---|
| Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 67" | | Dist. Aft of Motor 48"<br>Dist. from ℄ of Motor 22" | |
| Time | Temperature | Time | Temperature |
| Sec. | °F | Sec. | °F |
| 0 | 68 | 0 | 68 |
| 10 | 89 | 11 | 75 |
| 30 | 106 | 31 | 92 |
| 107 | 84 | 108 | 120 |
| 156 | 80 | 137 | 124 |

## TABLE III a

## TEMPERATURE SURVEY

Run #73 Duration of Run 45.1 sec. Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 2.03 Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Seconds | °F | °F | ΔT | $\Delta T_c$ |
| 13 | 5 | 10 | 500 | 56 | 444 | 710 |
| 19 | 6 | 11 | 500 | 57 | 443 | 681 |
| 25 | 7 | 13 | 475 | 57 | 418 | 590 |
| 31 | 9 | 25 | 348 | 57 | 291 | 331 |
| 37 | 10 | 28 | 276 | 57 | 219 | 244 |
| 43 | 11 | 29 | 210 | 57 | 153 | 168 |
| 49 | 13 | 35 | 154 | 58 | 96 | 102 |
| 55 | 14 | 37 | 111 | 58 | 53 | 56 |
| 61 | 15 | 40 | 100 | 58 | 42 | 44 |

# TABLE III b

## TEMPERATURE SURVEY

Run #74    Duration of Run 45 sec.    Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 1.69    Distance Aft of Nozzle 26.5 ft.

| Distance from $\mathcal{C}$ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| (inches) | | (sec.) | (°F) | (°F) | $\Delta T$ | $\Delta T_c$ |
| 13 | 5 | 22 | 500 | 48 | 452 | 532 |
| 19 | 6 | 23 | 500 | 49 | 451 | 525 |
| 25 | 7 | 24 | 460 | 52 | 408 | 470 |
| 31 | 9 | 39 | 318 | 47 | 271 | 282 |
| 37 | 10 | 40 | 282 | 47 | 235 | 244 |
| 43 | 11 | 50 | 150 | 46 | 104 | 105 |
| 49 | 13 | 53 | 104 | 52 | 52 | 53 |
| 55 | 14 | 54 | 80 | 54 | 26 | 26 |

## TABLE III c

## TEMPERATURE SURVEY

Run # 75  Duration of Run 45.0 sec.  Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 1.70  Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 29 | 6 | 10 | 315 | 72 | 243 | 389 |
| 35 | 7 | 14 | 218 | 72 | 146 | 200 |
| 41 | 9 | 18 | 177 | 71 | 106 | 132 |
| 47 | 10 | 25 | 136 | 72 | 64 | 73 |
| 53 | 11 | 26 | 104 | 72 | 32 | 36 |
| 59 | 13 | 30 | 94 | 72 | 22 | 24 |
| 65 | 14 | 31 | 85 | 72 | 13 | 14 |
| 71 | 15 | 32 | 83 | 72 | 11 | 12 |

# TABLE III d

## TEMPERATURE SURVEY

Run #77 Duration of Run 44.8 sec. Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 1.40 Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | $\Delta T$ | $\Delta T_c$ |
| 59 | 11 | 1 | 91 | 68 | 23 | |
| 67 | 13 | 6 | 89 | 68 | 21 | 47 |
| 71 | 14 | 7 | 84 | 68 | 16 | 32 |
| 77 | 15 | 8 | 80 | 68 | 12 | 22 |
| 29 | 6 | 29 | 426 | 68 | 358 | 394 |

## TABLE III e

## TEMPERATURE SURVEY

Run #78 Duration of Run 45 sec. Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 1.38 Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec | °F | °F | ΔT | $\Delta T_c$ |
| 29 | 6 | 21 | 428 | 76 | 352 | 421 |
| 35 | 7 | 22 | 382 | 80 | 302 | 356 |
| 41 | 9 | 39 | 284 | 76 | 208 | 216 |
| 47 | 10 | 40 | 158 | 76 | 82 | 85.5 |
| 53 | 11 | 46 | 115 | 78 | 37 | 37.8 |
| 59 | 13 | 51 | 100 | 75 | 25 | 25.2 |
| 65 | 14 | 52 | 92 | 76 | 16 | 16 |
| 71 | 15 | 53 | 90 | 79 | 11 | 11 |

## TABLE III f

## TEMPERATURE SURVEY

Run #30 Duration of Run 45.2 sec. Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ration 2.36 Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 47 | 10 | 1 | 127 | 85 | 42 | - |
| 59 | 13 | 9 | 110 | 82 | 28 | 46 |
| 65 | 14 | 10 | 102 | 80 | 22 | 35.2 |
| 71 | 15 | 11 | 96 | 84 | 12 | 18.5 |
| 17 | 3 | 20 | 480 | 85 | 395 | 476 |
| 23 | 5 | 40 | 421 | 85 | 336 | 350 |
| 29 | 6 | 44 | 346 | 85 | 261 | 268 |

## TABLE III 9

## TEMPERATURE SURVEY

Run 31 Duration of Run 45.2 sec. Motor M-272

Fuel 80% Aniline 20% FUOH

Oxidizer 6 1/2% RFNA

Mixture Ratio 2.36 Distance Aft of Nozzle 26.5 ft.

| Distance from ℄ of Motor | Thermocouple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermocouple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 27 | 3 | 422 | 25 | 56 | 366 | 419 |
| 31 | 5 | 225 | 35 | 56 | 190 | 202 |
| 37 | 6 | 190 | 36 | 56 | 154 | 162 |
| 43 | 7 | 121 | 40 | 56 | 81 | 84.5 |
| 49 | 9 | 93 | 42 | 53 | 51 | 52.5 |
| 55 | 10 | 80 | 43 | 56 | 37 | 38 |
| 61 | 11 | 66 | 44 | 54 | 22 | 22.4 |

## TABLE IV a

## TEMPERATURE SURVEY

Run #82 Duration of Run 40 sec. Motor M-293

Fuel 80% Aniline 20% FUOH

Oxidizer WFNA

Mixture Ratio 1.75 Distance Aft of Nozzle 24.5 ft.

| Distance from ℄ of Motor | Thermocouple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermocouple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 41 | 3 | 9 | 248 | 72 | 100 | 352 |
| 47 | 5 | 10 | 172 | 72 | 62 | 167 |
| 53 | 6 | 11 | 134 | 72 | 35 | 100 |
| 59 | 7 | 14 | 106 | 71 | 20 | 54 |
| 65 | 9 | 15 | 92 | 72 | 10 | 28 |
| 71 | 10 | 16 | 82 | 72 | 6 | 13 |
| 77 | 11 | 18 | 78 | 72 | 5 | 8 |
| 83 | 13 | 19 | 77 | 72 | 2 | 6 |
| 89 | 14 | 20 | 74 | 72 | 3 | 3 |
| 95 | 15 | 31 | 74 | 71 | 142 | 4 |

## TABLE IV b

## TEMPERATURE SURVEY

Run #83 Duration of Run 45.3 sec. Motor M-293

Fuel FUQH

Oxidizer WFNA

Mixture Ratio 1.77 Distance Aft of Nozzle 24.5 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 41 | 3 | 15 | 226 | 63 | 163 | 218 |
| 47 | 5 | 23 | 187 | 64 | 123 | 143 |
| 53 | 6 | 26 | 132 | 58 | 74 | 83.5 |
| 59 | 7 | 33 | 102 | 62 | 40 | 43 |
| 65 | 9 | 38 | 70 | 55 | 15 | 16 |
| 71 | 10 | 39 | 69 | 62 | 7 | 7 |
| 77 | 11 | 40 | 67 | 62 | 5 | 5 |
| 83 | 13 | 42 | 67 | 62 | 5 | 5 |
| 89 | 14 | 43 | 66 | 63 | 3 | 3 |
| 95 | 15 | 44 | 64 | 62 | 2 | 2 |

## TABLE V a

## TEMPERATURE SURVEY

Run #85 Duration of Run 49.9 sec. Motor M-293

Fuel FUOH

Oxidizer WFNA

Mixture Ratio 2.22 Distance Aft of Motor 22 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 41 | 3 | 11 | 134 | 60 | 74 | 114 |
| 47 | 5 | 13 | 116 | 68 | 47 | 67 |
| 53 | 6 | 19 | 84 | 68 | 16 | 30 |
| 59 | 7 | 20 | 74 | 68 | 6 | 7 |
| 65 | 9 | 25 | 73 | 68 | 5 | 6 |
| 71 | 10 | 26 | 70 | 68 | 2 | 2 |
| 77 | 11 | 27 | 69 | 68 | 1 | 1 |
| 83 | 13 | 30 | 69 | 66 | 3 | 3 |
| 89 | 14 | 31 | 66 | 64 | 2 | 2 |
| 95 | 15 | 32 | 69 | 66 | 3 | 3 |

## TABLE V b

## TEMPERATURE SURVEY

Run #87 Duration of Run 45 sec. Motor M-293

Fuel FUOH

Oxidizer WFNA

Mixture Ratio 2.46 Distance Aft of Nozzle 22 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 36 | 5 | 14 | 142 | 58 | 84 | 116 |
| 42 | 6 | 16 | 100 | 58 | 42 | 55 |
| 48 | 7 | 18 | 80 | 58 | 22 | 28 |
| 54 | 9 | 21 | 72 | 58 | 14 | 17 |
| 60 | 10 | 23 | 65 | 58 | 7 | 8 |
| 66 | 11 | 24 | 63 | 58 | 5 | 6 |
| 72 | 13 | 28 | 63 | 58 | 5 | 6 |
| 78 | 14 | 29 | 62 | 58 | 4 | 4 |
| 84 | 15 | 30 | 62 | 58 | 4 | 4 |
| | 2 | 36 | 136 | 58 | 78 | 82 |
| 30 | 3 | 38 | 188 | 58 | 130 | 135 |

## TABLE Vc

## TEMPERATURE SURVEY

Run #88 Duration of Run 44.8 sec. Motor M-293

Fuel FUOH

Oxidizer WFNA

Mixture Ratio 2.22 Distance Aft of Nozzle 22 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| | 2 | 21 | 150 | 68 | 82 | 99 |
| 30 | 3 | 27 | 201 | 72 | 129 | 145 |
| 36 | 5 | 28 | 155 | 72 | 83 | 92 |
| 42 | 6 | 29 | 122 | 72 | 50 | 55 |
| 48 | 7 | 30 | 106 | 72 | 34 | 37 |
| 54 | 9 | 32 | 93 | 72 | 21 | 23 |
| 60 | 10 | 33 | 82 | 72 | 10 | 11 |
| 66 | 11 | 34 | 78 | 72 | 6 | 6 |
| 72 | 13 | 39 | 78 | 72 | 6 | 6 |
| 78 | 14 | 40 | 76 | 72 | 4 | 4 |
| 84 | 15 | 41 | 76 | 72 | 4 | 4 |

## TABLE V d

## TEMPERATURE SURVEY

Run # 98 Duration of Run 45.6 sec. Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 2.40 Distance Aft of Motor 22 ft.

| Distance from of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp.Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | ΔT | $\Delta T_c$ |
| 36 | 5 | 17 | 280 | 76 | 204 | 262 |
| 41 | 6 | 26 | 221 | 76 | 145 | 163 |
| 46 | 7 | 27 | 186 | 76 | 110 | 123 |
| 51 | 9 | 31 | 136 | 76 | 60 | 65 |
| 56 | 10 | 32 | 116 | 76 | 40 | 43 |
| 60 | 11 | 33 | 101 | 76 | 25 | 27 |
| 65 | 13 | 40 | 90 | 76 | 14 | 15 |
| 70 | 14 | 41 | 80 | 74 | 6 | 6 |
| 75 | 15 | 42 | 78 | 76 | 2 | 2 |

## TABLE VI a

## TEMPERATURE SURVEY

Run #89 Duration of Run 44.3 sec. Motor M-293

Fuel FUOH

Oxidizer WFNA

Mixture Ratio 1.74 Distance Aft of Nozzle 19 ft.

| Distance from ℄ of Motor | Thermocouple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermocouple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | Sec. | °F | °F | $\Delta T$ | $\Delta T_c$ |
| 30 | 3 | 18 | 270 | 84 | 186 | 236 |
| 36 | 5 | 21 | 191 | 85 | 106 | 128 |
| 42 | 6 | 22 | 144 | 85 | 59 | 70 |
| 48 | 7 | 23 | 114 | 85 | 29 | 34 |
| 54 | 9 | 26 | 94 | 84 | 10 | 11 |
| 60 | 10 | 28 | 88 | 84 | 4 | 4 |
| 66 | 11 | 29 | 86 | 84 | 2 | 2 |
| 72 | 13 | 30 | 86 | 84 | 2 | 2 |
| 78 | 14 | 31 | 85 | 84 | 1 | 1 |
| 84 | 15 | 32 | 83 | 83 | 0 | 0 |

## TABLE VI b

## TEMPERATURE SURVEY

Run #90 Duration of Run 45.2 sec. Motor M-293

Fuel FUOH

Oxidizer

Mixture Ratio 1.73 Distance Aft of Nozzle 19 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| 30 | 3 | 15 | 277 | 73 | 204 | 267 |
| 36 | 5 | 17 | 200 | 73 | 127 | 163 |
| 42 | 6 | 20 | 134 | 73 | 61 | 73 |
| 48 | 7 | 22 | 92 | 72 | 20 | 24 |
| 54 | 9 | 25 | 84 | 72 | 12 | 14 |
| 60 | 10 | 26 | 83 | 72 | 11 | 12 |
| 66 | 11 | 27 | 82 | 73 | 9 | 10 |
| 72 | 13 | 29 | 81 | 72 | 9 | 10 |
| 78 | 14 | 30 | 81 | 72 | 9 | 10 |
| 84 | 15 | 31 | 80 | 72 | 8 | 9 |
| | 2 | 39 | 236 | 64 | 172 | 179 |

## TABLE VI c

## TEMPERATURE SURVEY

Run 91 Duration of Run 45 sec. Motor M-293

Fuel FUOH

Oxidizer 90% WFNA 10% $H_2O$

Mixture Ratio 2.01 Distance Aft of Nozzle 19 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| *18 | 2 | 21 | 97 | 72 | 22 | 26 |
| 30 | 3 | 23 | 230 | 77 | 153 | 178 |
| 36 | 5 | 26 | 158 | 77 | 81 | 91 |
| 42 | 6 | 30 | 109 | 77 | 32 | 35 |
| 48 | 7 | 31 | 90 | 77 | 13 | 14 |
| 54 | 9 | 33 | 87 | 77 | 10 | 11 |
| 60 | 10 | 34 | 87 | 77 | 10 | 11 |
| 66 | 11 | 36 | 87 | 77 | 10 | 11 |
| 72 | 13 | 40 | 86 | 76 | 10 | 10 |
| 78 | 14 | 41 | 86 | 76 | 10 | 10 |
| 84 | 15 | 42 | 86 | 76 | 10 | 10 |

*Distance aft of Motor 4 in.

## TABLE VI d

## TEMPERATURE SURVEY

Run # 97    Duration of Run 44.6 sec.    Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $N_2O$

Mixture Ratio 2.19    Distance Aft of Motor 19 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp.Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| 33 | 5 | 30 | 285 | 88 | 197 | 216 |
| 38 | 6 | 32 | 217 | 88 | 129 | 139 |
| 43 | 7 | 34 | 155 | 87 | 68 | 72 |
| 48 | 9 | 36 | 121 | 86 | 35 | 37 |
| 53 | 10 | 37 | 97 | 86 | 11 | 12 |
| 57 | 11 | 39 | 91 | 86 | 5 | 5 |
| 62 | 13 | 41 | 87 | 86 | 1 | 1 |

## TABLE VII a

## TEMPERATURE SURVEY

Run #92  Duration of Run 45 sec.  Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 2.20  Distance Aft of Motor 16 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| 30 | 3 | 28 | 256 | 90 | 166 | 185 |
| 36 | 5 | 32 | 186 | 89 | 97 | 104 |
| 42 | 6 | 34 | 122 | 91 | 31 | 33 |
| 48 | 7 | 35 | 98 | 89 | 9 | 9 |
| 54 | 9 | 39 | 94 | 88 | 6 | 6 |
| 60 | 10 | 40 | 93 | 89 | 4 | 4 |
| 66 | 11 | 41 | 93 | 89 | 4 | 4 |
| 72 | 13 | 42 | 92 | 88 | 4 | 4 |
| 78 | 14 | 43 | 92 | 88 | 4 | 4 |
| 84 | 15 | 44 | 91 | 88 | 3 | 3 |

## TABLE VII b

## TEMPERATURE SURVEY

Run #93    Duration of Run 44.7 sec.    Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 2.47    Distance Aft of Motor 16 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | $\Delta T$ | $\Delta T_c$ |
| 72 | 13 | 16 | 96 | 97 | -1 | -1 |
| 78 | 14 | 17 | 96 | 97 | -1 | -1 |
| 84 | 15 | 18 | 96 | 97 | -1 | -1 |
| 30 | 3 | 24 | 215 | 98 | 117 | 134 |
| 36 | 5 | 28 | 134 | 98 | 36 | 40 |
| 42 | 6 | 29 | 105 | 98 | 7 | 8 |
| 48 | 7 | 30 | 100 | 98 | 2 | 2 |
| 54 | 9 | 32 | 99 | 98 | 1 | 1 |
| 60 | 10 | 33 | 98 | 98 | 0 | 0 |
| 66 | 11 | 34 | 98 | 98 | 0 | 0 |

## TABLE VII c

## TEMPERATURE SURVEY

Run 95 Duration of Run 45.4 sec. Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 1.73 Distance Aft of Motor 16 ft.

| Distance from ℄ of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| 30 | 3 | 24 | 321 | 94 | 227 | 256 |
| 36 | 5 | 31 | 205 | 93 | 112 | 121 |
| 42 | 6 | 32 | 131 | 93 | 38 | 41 |
| 48 | 7 | 33 | 112 | 93 | 19 | 20 |
| 54 | 9 | 35 | 109 | 93 | 16 | 17 |
| 60 | 10 | 36 | 107 | 93 | 14 | 15 |
| 66 | 11 | 37 | 105 | 93 | 12 | 13 |
| 72 | 13 | 40 | 104 | 93 | 11 | 11 |
| 78 | 14 | 41 | 103 | 94 | 9 | 9 |
| 84 | 15 | 42 | 99 | 94 | 5 | 5 |

# TABLE VII d

## TEMPERATURE SURVEY

Run #96 Duration of Run 45.4 sec. Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 2.01 Distance Aft of Motor 16 ft.

| Distance from ℄ of Motor | Thermocouple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermocouple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | ΔT | $\Delta T_c$ |
| 33 | 5 | 22 | 260 | 95 | 165 | 195 |
| 38 | 6 | 27 | 179 | 94 | 85 | 95 |
| 48 | 7 | 29 | 119 | 94 | 25 | 27 |
| 53 | 9 | 31 | 102 | 94 | 8 | 9 |
| 57 | 10 | 32 | 100 | 94 | 6 | 6 |
| 62 | 11 | 33 | 96 | 93 | 3 | 3 |
| 67 | 13 | 37 | 94 | 91 | 3 | 3 |
| 72 | 14 | 38 | 94 | 91 | 3 | 3 |
| 77 | 15 | 39 | 93 | 91 | 2 | 2 |

## TABLE VIII a

## TEMPERATURE SURVEY

Run #99 Duration of Run 45 sec. Motor M-293

Fuel **FUOH**

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 1.24 Distance from ℄ 24"

| Distance Aft of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | $\Delta T$ | $\Delta T_c$ |
| 33 | 9 | 4 | 110 | 52 | 68 | 194 |
| 27 | 10 | 5 | 100 | 63 | 37 | 92 |
| 21 | 11 | 6 | 86 | 61 | 25 | 54 |
| 15 | 13 | 8 | 84 | 64 | 20 | 36 |
| 9 | 14 | 9 | 84 | 66 | 18 | 31 |
| 3 | 15 | 10 | 82 | 66 | 16 | 26 |
| 51 | 5 | 32 | 240 | 62 | 278 | 299 |

## TABLE VIII b

## TEMPERATURE SURVEY

Run #100    Duration of Run 59.9 sec.    Motor M-293

Fuel FUOH

Oxidizer 90% WFNA & 10% $H_2O$

Mixture Ratio 2.78    Distance from ℄ of Motor 36"

| Distance Aft of Motor | Thermo-couple Number | Time of Reading after Start of Run | Temp. | Temp. of Thermo-couple before Run | Temp. Rise | Temp. Rise Corrected for Thermo. Response |
|---|---|---|---|---|---|---|
| inches | | sec. | °F | °F | $\Delta T$ | $\Delta T_c$ |
| 61 | 2 | 50 | 115 | 60 | 55 | 55 |
| 55 | 3 | 51 | 86 | 60 | 26 | 26 |
| 51 | 5 | 55 | 96 | 59 | 35 | 35 |
| 45 | 6 | 56 | 98 | 59 | 37 | 37 |
| 39 | 7 | 57 | 95 | 58 | 37 | 37 |
| 15 | 9 | 60 | 88 | 59 | 37 | 29 |
| 27 | 10 | 40 | 92 | 59 | 33 | 34 |
| 21 | 11 | 41 | 91 | 59 | 32 | 33 |
| 33 | 13 | 44 | 96 | 59 | 29 | 38 |
| 9 | 14 | 45 | 84 | 59 | 25 | 26 |
| 3 | 15 | 46 | 80 | 59 | 21 | 21 |

## TABLE IX

## VELOCITY SURVEY

Distance Aft of Motor 24.5 ft.

| Distance from of Motor | Alcohol Temp. | (inches of Alcohol) | Run Number | Ambient Air Temp. | with rack to of Motor | with rack at 37° | Direction of flow | Speed of flow |
|---|---|---|---|---|---|---|---|---|
| inches | °F | inches | | °F | #/ft$^2$ | #/ft$^2$ | Degrees | ft/sec |
| 30 | 65 | 1.32 | 98 | 76 | (7.6)* | 5.42 | 2** | 69.0 |
| 34 | 69 | 1.32 | 83 | 62 | 5.4 | | | |
| 35 | 65 | 0.95 | 98 | 76 | (4.7) | 3.90 | 6 | 64.5 |
| 40 | 69 | 0.61 | 83 | 62 | 2.5 | | | |
| 40 | 65 | 0.35 | 98 | 76 | (2.5) | 1.44 | 3 | 46.9 |
| 46 | 69 | 0.12 | 83 | 62 | 0.49 | | | |
| 45 | 65 | 0.14 | 98 | 76 | (0.70) | 0.58 | 6 | 24.6 |
| 52 | 69 | 0.01 | 83 | 62 | 0.04 | | | |
| 49 | 65 | 0.07 | 98 | 76 | (0.10) | 0.29 | 46 | 9.4 |

* () Numbers derived from data not in () in this column.

** Degrees are positive when flow is toward of Motor.

## TABLE X

## VELOCITY SURVEY

Distance Aft of Motor 22 ft.

| Distance from of Motor | Alcohol Temp. | (inches of Alcohol) | Run Number | Ambient Air Temp. | with rack to of Motor | with rack at 37° | Direction of flow | Speed of flow |
|---|---|---|---|---|---|---|---|---|
| inches | °F | inches | | °F | #/ft² | #/ft² | degrees | ft/sec |
| 30 | 65 | 1.98 | 86 | 64 | 8.14 | (6.6) | -5° | 85.3 |
| 32 | 75 | 1.31 | 97 | 86 | | 5.34 | | |
| 36 | 65 | 0.74 | 86 | 64 | 3.04 | (1.9) | +2 | 52.1 |
| 38 | 75 | 0.29 | 97 | 86 | | 1.2 | | |
| 42 | 65 | 0.14 | 86 | 64 | 0.58 | (0.60) | 22 | 23.6 |
| 44 | 75 | 0.10 | 97 | 86 | | 0.41 | | |
| 48 | 65 | 0.004 | 86 | 64 | 0.016 | (0.05) | 46 | 6.7 |
| 50 | 75 | 0.003 | 97 | 86 | | 0.012 | | |

## TABLE XI

## VELOCITY SURVEY

Distance Aft of Motor 19 ft.

| Distance from of Motor | Alcohol Temp. | (inches of Alcohol) | Run Number | Ambient Air Temp. | with rack to of Motor | with rack at 37° | Direction of flow | Speed of flow |
|---|---|---|---|---|---|---|---|---|
| inches | °F | inches | | °F | #/ft² | #/ft² | degrees | ft/sec |
| 23 | 66 | 3.2 | 90 | 72 | 13.18 | | | |
| 23 | 82 | 0.63 | 96 | | | 2.56 | -11° | 221 |
| 29 | 66 | 1.03 | 90 | 72 | 4.24 | | | |
| 29 | 82 | 0.32 | 96 | | | 1.3 | -10° | 125 |

# TABLE XII

## VELOCITY SURVEY

Distance Aft of Motor 16 ft.

| Distance from of Motor | Alcohol Temp. | (inches of Alcohol) | Run Number | Ambient Air Temp. | with rack to of Motor | with rack at 37° | Direction of flow | Speed of flow |
|---|---|---|---|---|---|---|---|---|
| inches | °F | inches | | °F | #/ft² | #/ft² | degrees | ft/sec |
| 23 | 75 | 2.5 | 92 | 89 | 10.2 | | | |
| 23 | 82 | 3.4 | 95 | 93 | | 13.8 | 35° | 114 |
| 29 | 75 | 0.61 | 92 | 89 | 2.5 | | | |
| 29 | 82 | 0.84 | 95 | 93 | | 3.41 | 35° | 57 |

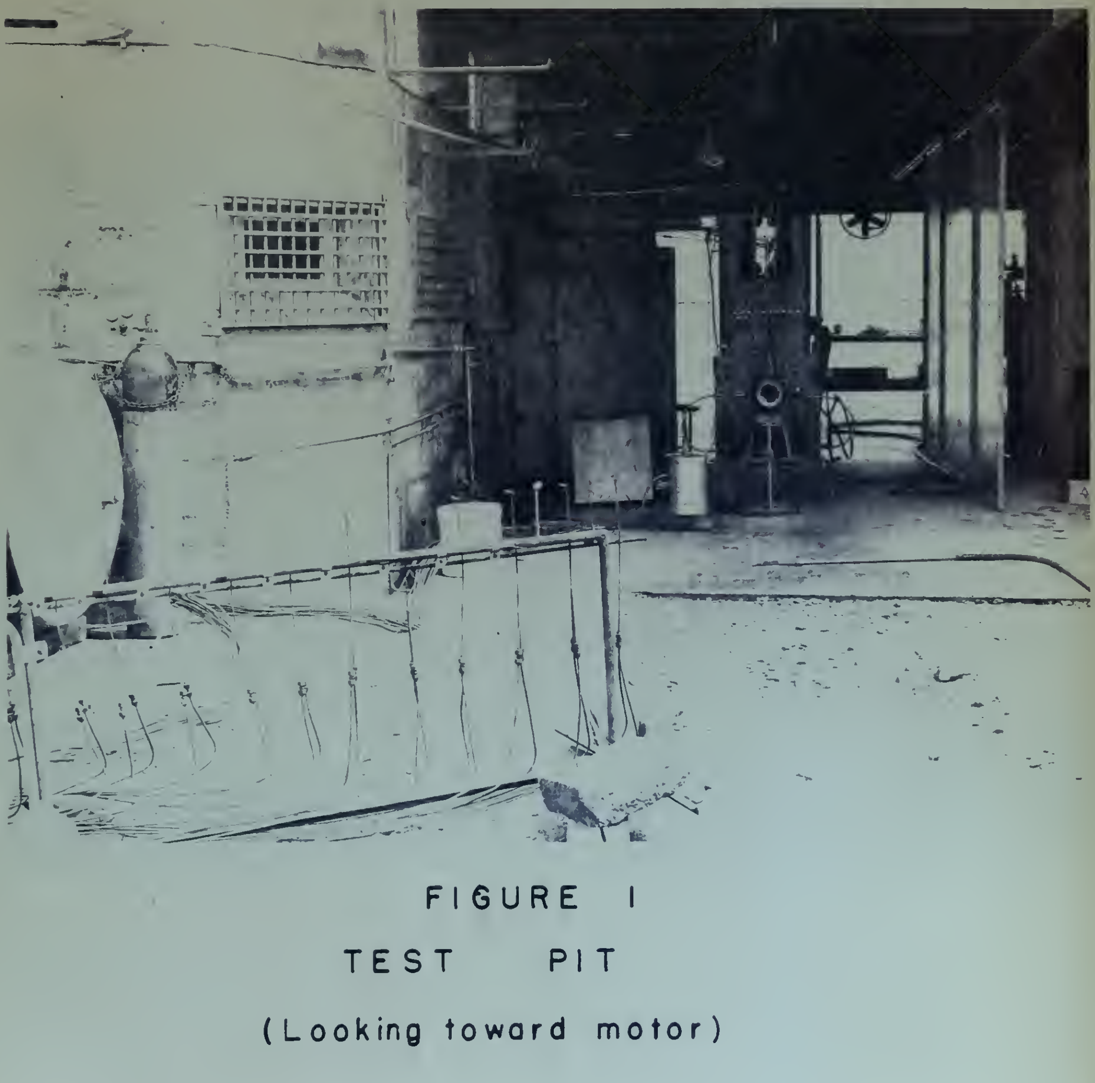


FIGURE I

TEST PIT

(Looking toward motor)

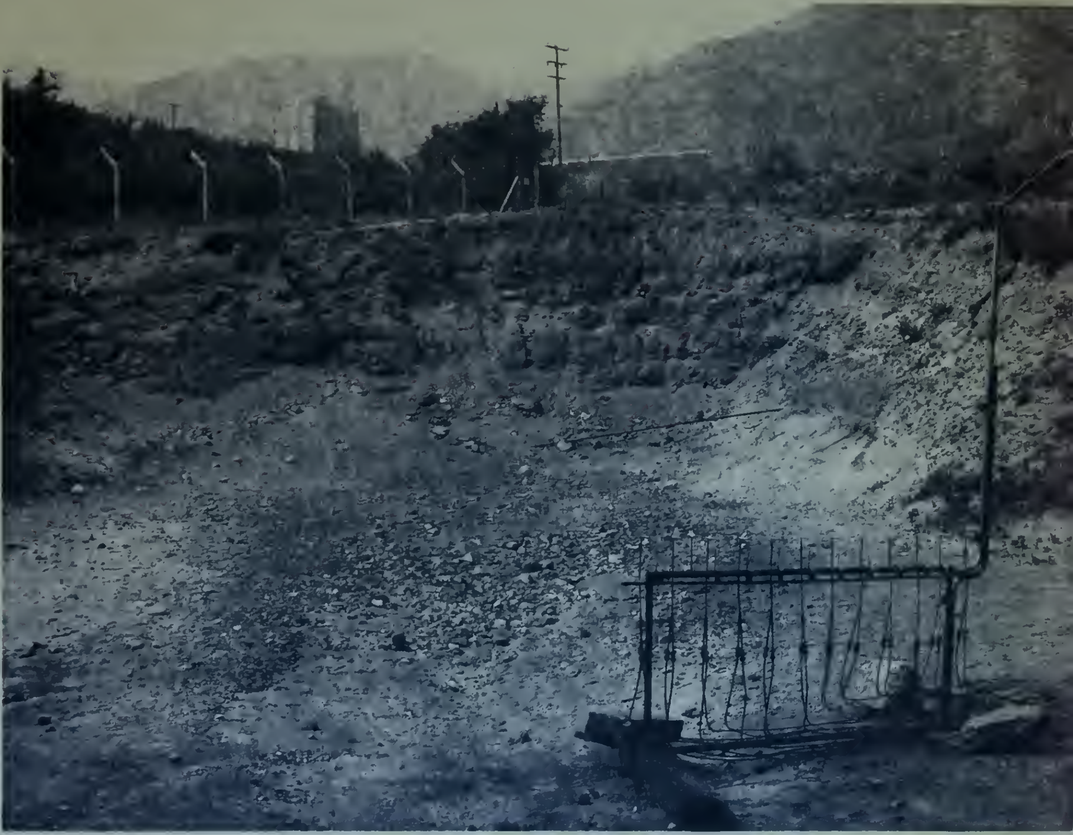


FIGURE 2

TEST PIT

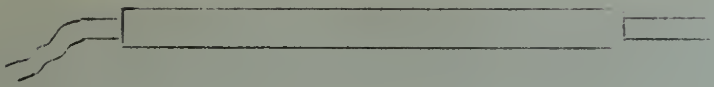
(Looking aft from motor. Rack in right foreground.)

## FIGURE 3

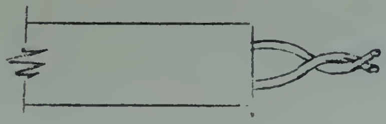
## CONSTRUCTION OF AN IRON-CONSTANTAN

## THERMOCOUPLE

A. Insert wires into porcelain tubing:

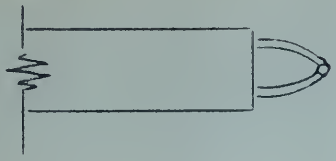


$B_1$. Twist wires as shown in the enlarged diagram and braze, making a small bead of metal which may be blackened with soot.



$B_2$. Twist the wires as shown but cut so wires cross only once. Silver solder this junction.

C. With either method ( $B_1$ or $B_2$ ) the finished thermocouple will be as follows:



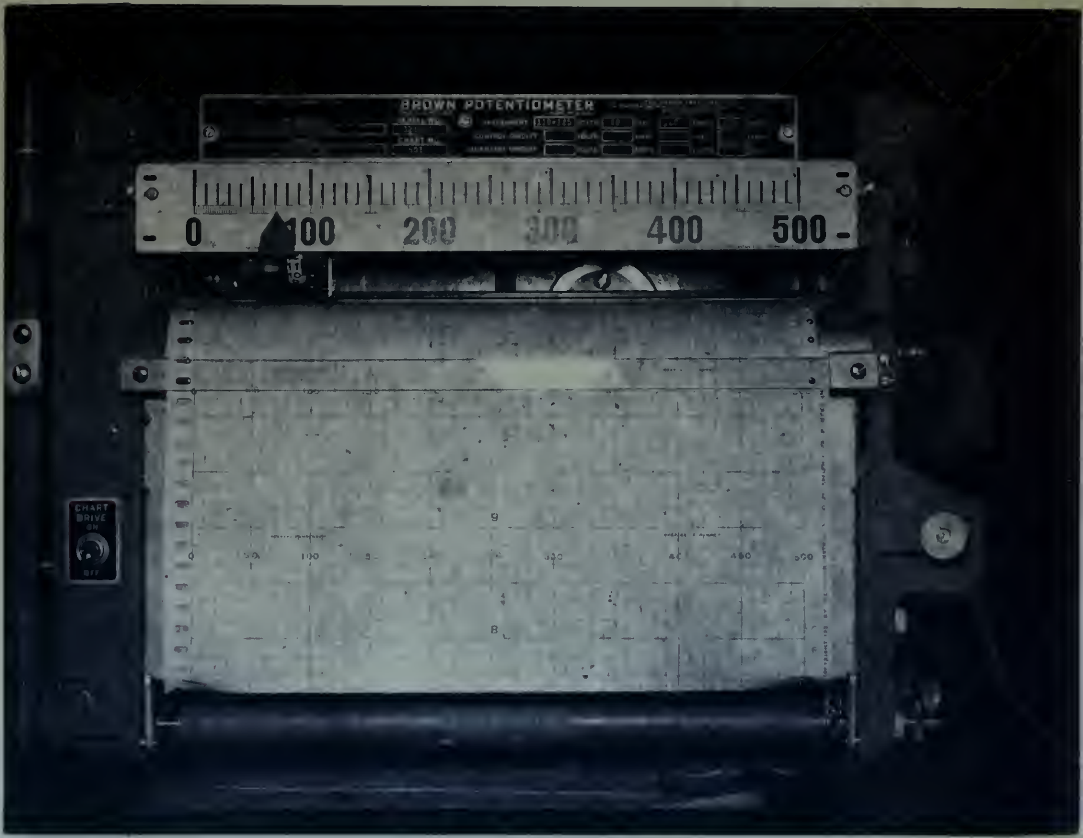


FIGURE 4

BROWN POTENTIOMETER

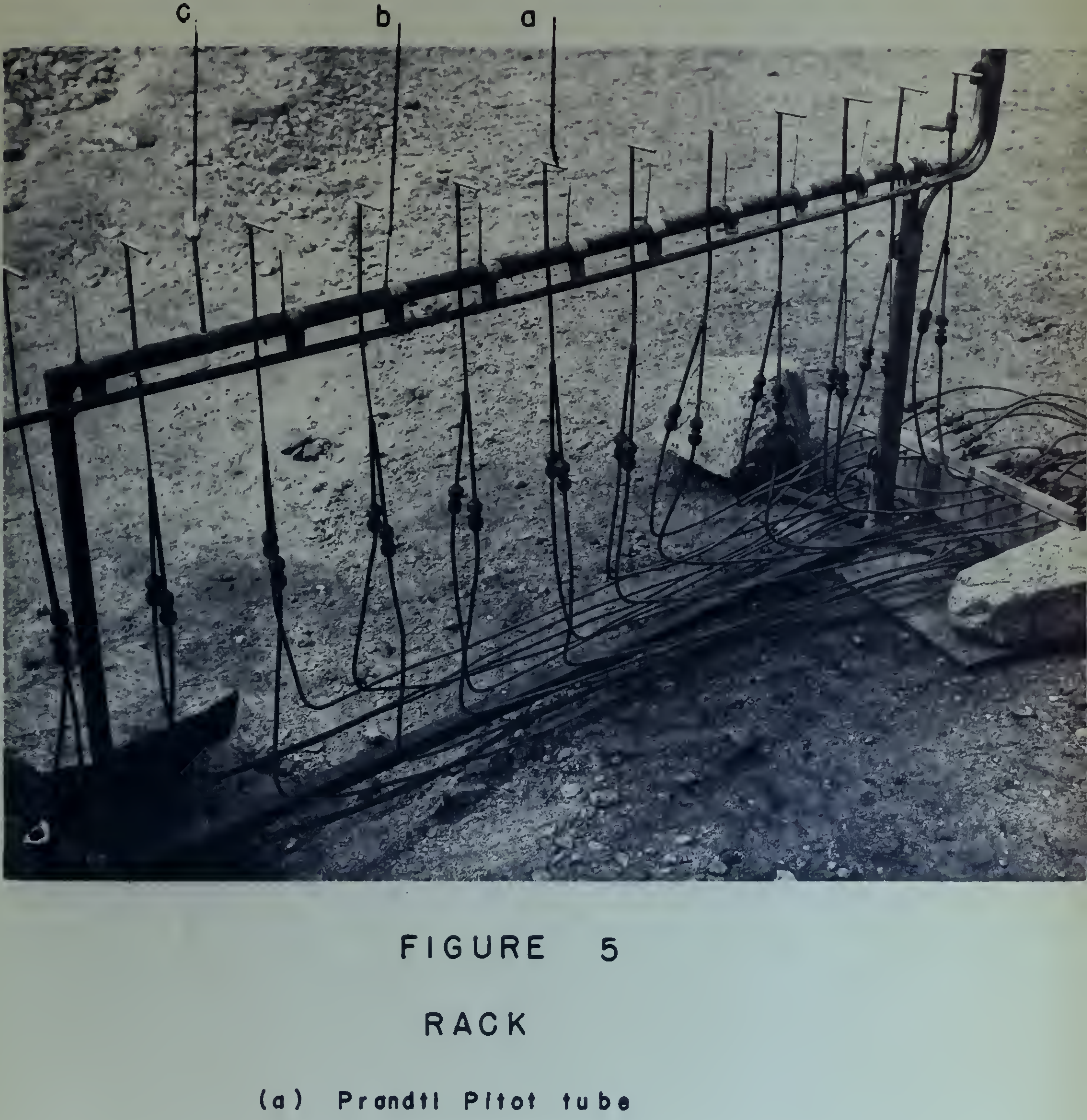


FIGURE 5

RACK

(a) Prandtl Pitot tube

(b) Thermocouple

(c) Stagnation temperature probe

FIGURE 6

SHIELDED THERMOCOUPLE

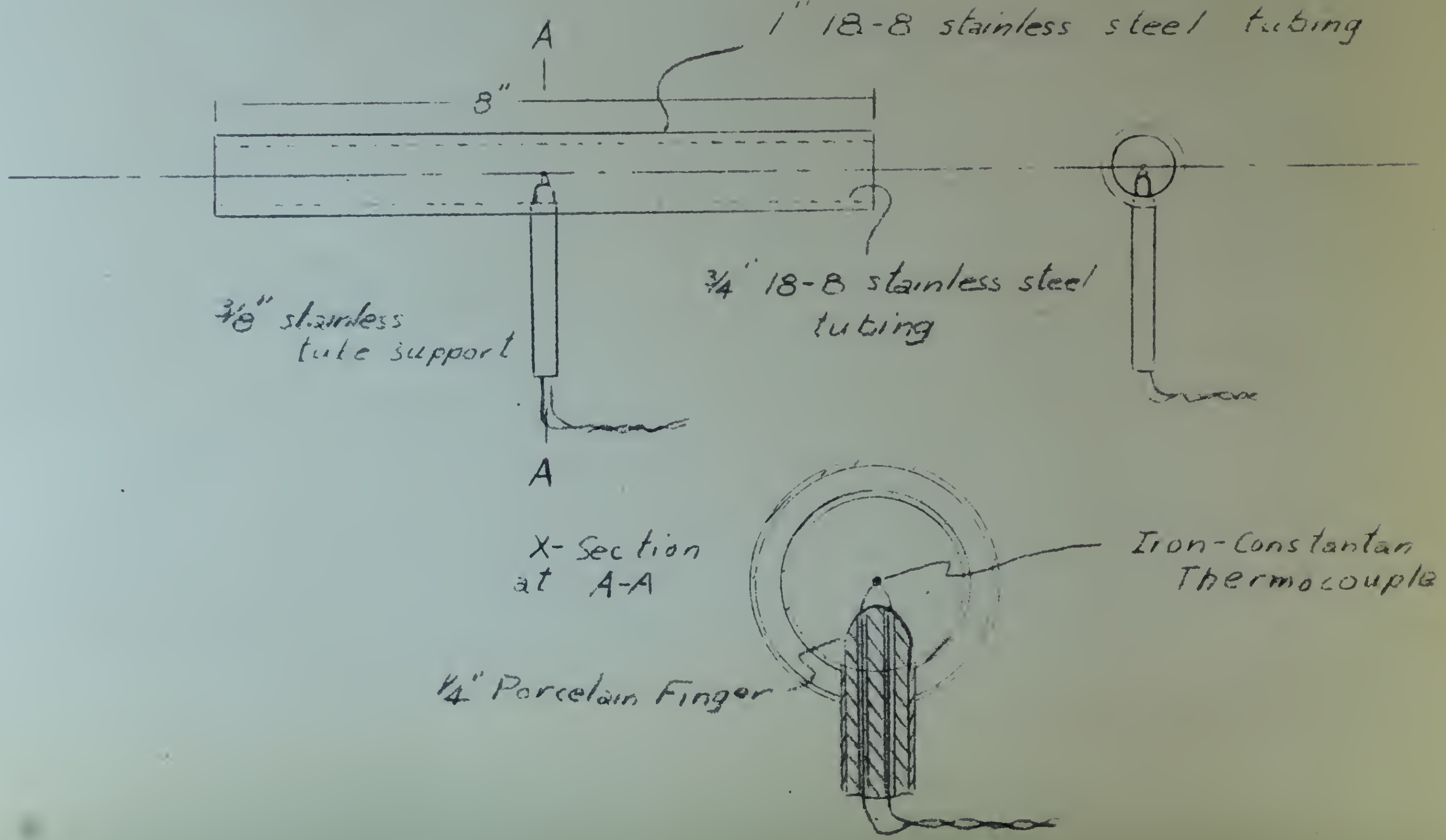
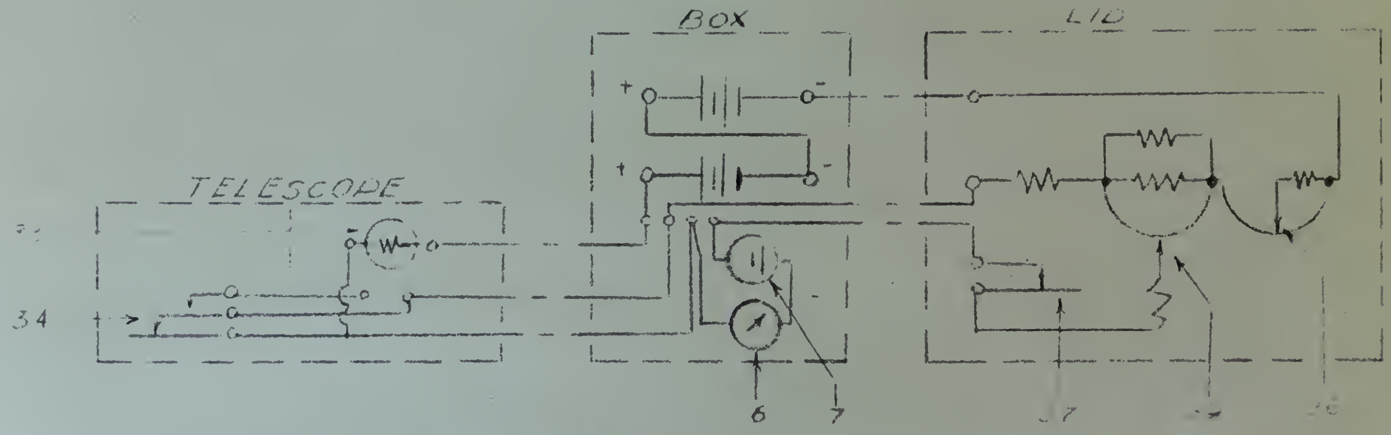

1" 18-8 stainless steel tubing
A
8"
3/8" stainless tube support
A
3/4" 18-8 stainless steel tubing
X-Section at A-A
Iron-Constantan Thermocouple
1/4" Porcelain Finger

Figure 7

## OPTICAL PYROMETER CIRCUIT



6 - Galvanometer

7 - Standard Cell

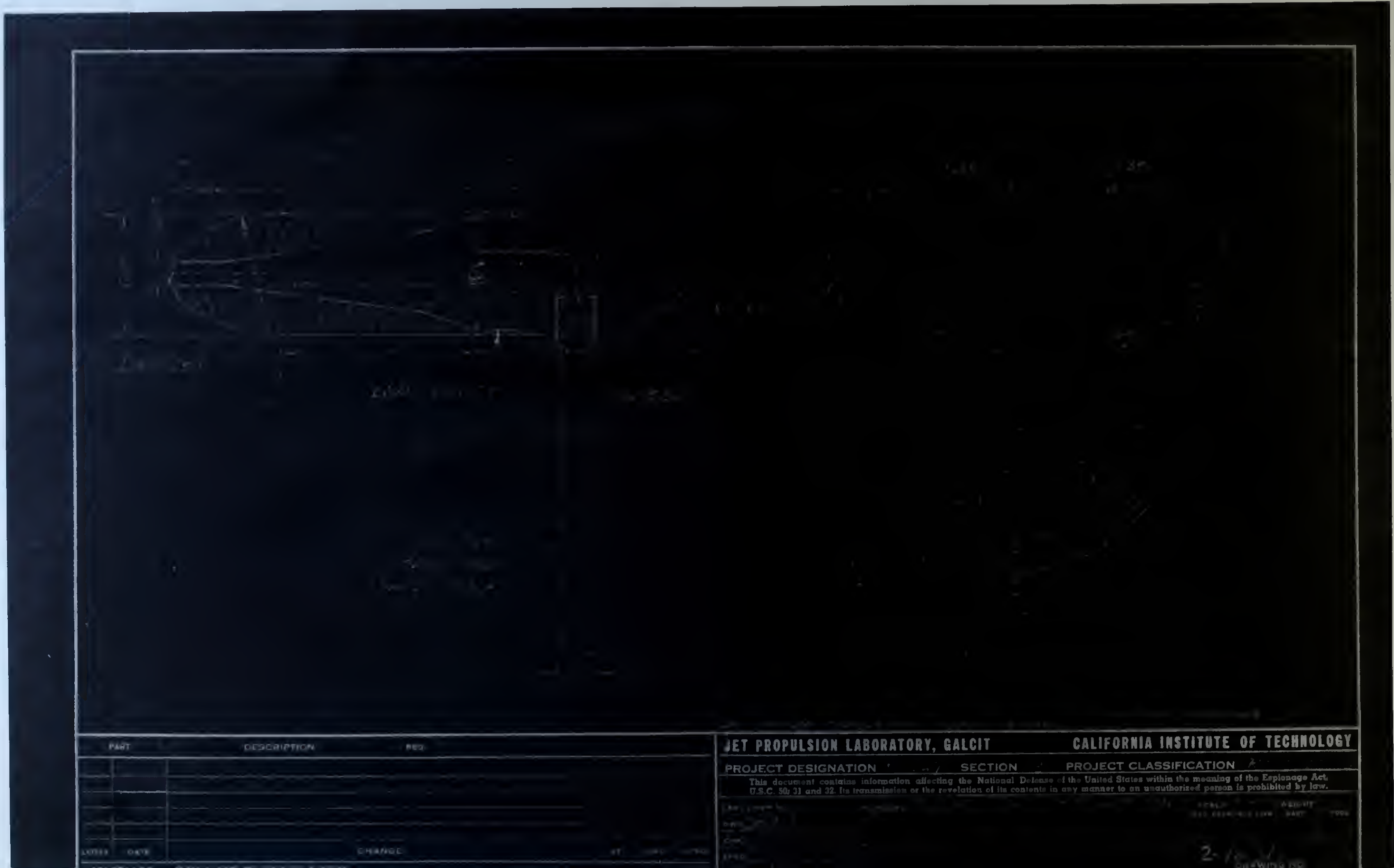
33 - Lamp

34 - Switch

37 - Switch

38 - 39 - Slide Wire Resistance

FIGURE 8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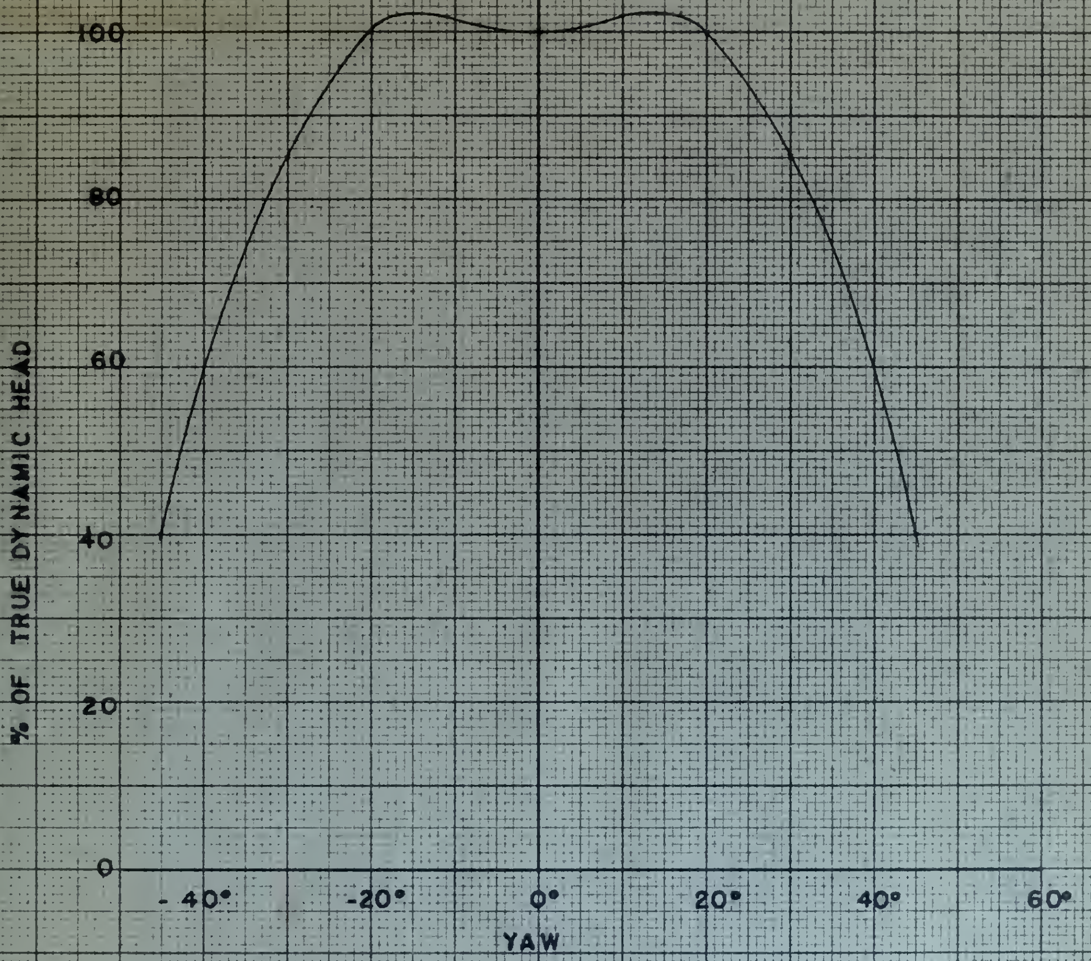
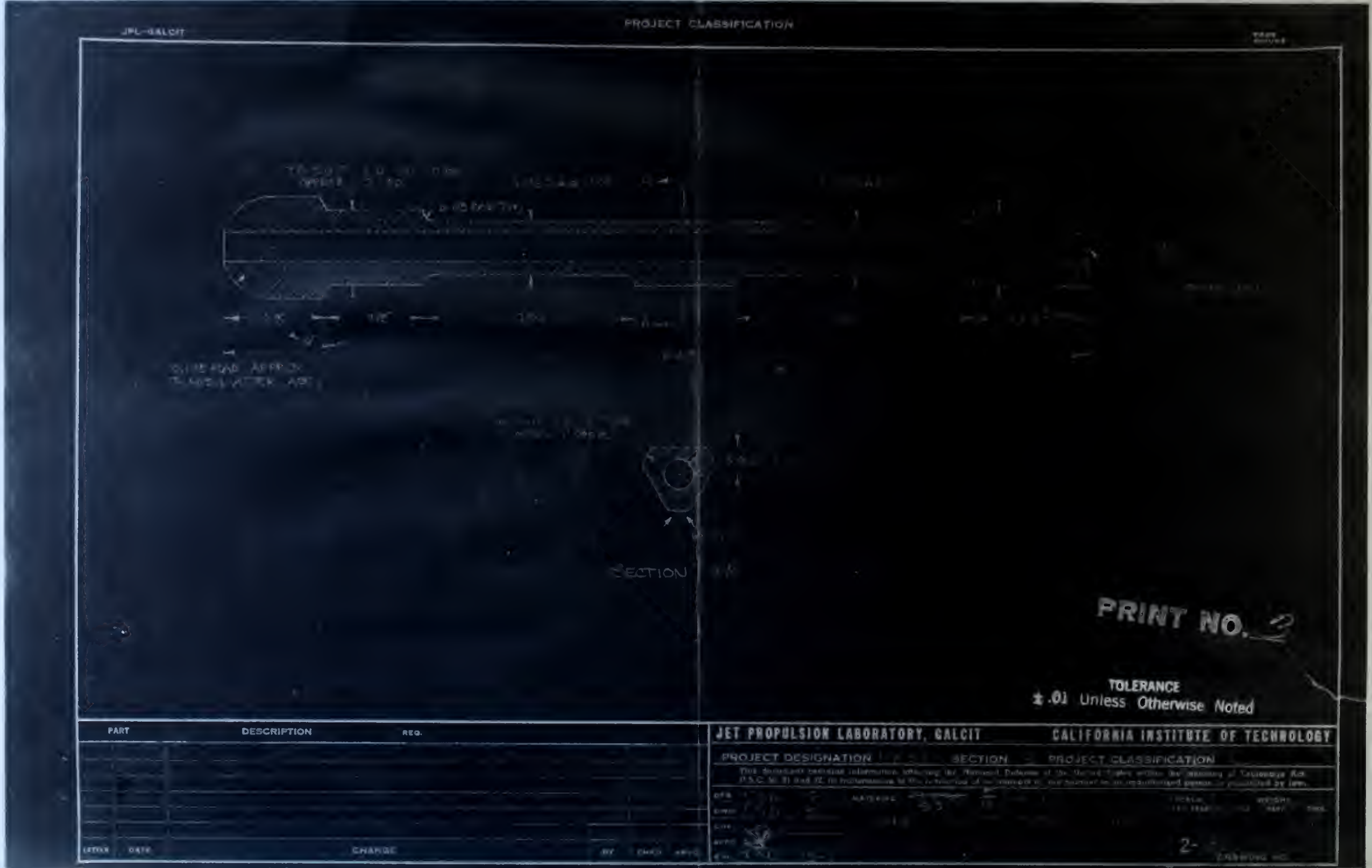


FIGURE 9

YAW CHARACTERISTICS OF
PRANDTLE TUBE

FIGURE 10a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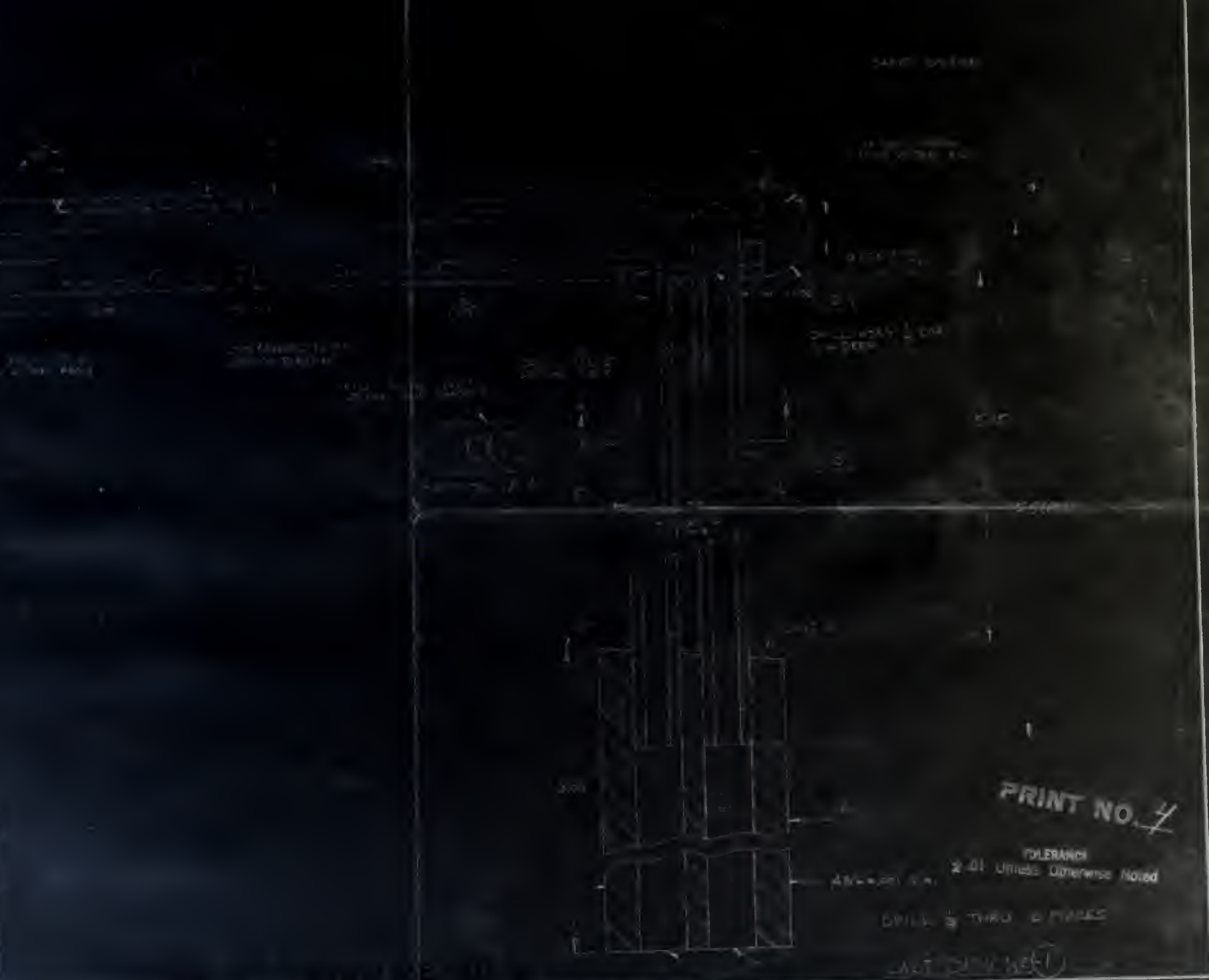

PRINT NO. 4

TOLERANCE
±.01 Unless Otherwise Noted

DRILL ⅛ THRU 6 PLACES

| PART | DESCRIPTION | REQ. |
|---|---|---|
| [illegible] | DIA STEEL [illegible] | 1 |
| 5 | ⅛ DIA COPPER [illegible] -2/6 | 1 |
| 4 | 1/16 DIA STAINLESS WIRE | 1 |
| 3 | ⅜ DIA COPPER TUBE [illegible] | 1 |
| 2 | ⅛ [illegible] | 1 |
| [illegible] | ½ x [illegible] TUBE | 1 |
| 1 | CORE | |

| LETTER | DATE | CHANGE | BY | CHKD. | APPD. |
|---|---|---|---|---|---|
| | | | | | |

1. [illegible] TO SLIP INTO [illegible] REMAINDER OF ASS'Y SWEAT SOLDERED IN PLACE

[illegible] PLATE [illegible] SLIT [illegible] PART OF ASS'Y [illegible]

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PROJECT DESIGNATION MX 527 SECTION 8 PROJECT CLASSIFICATION [redacted]

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DRN. [illegible] S-1 MATERIAL NOTED

DWN. S-1 [illegible] TUBE [illegible]

CKD.

APPD.

ENG.

SCALE ⅜" = 1" WEIGHT

ENG. EXAM. PROD. EXAM. PART

4-360
DRAWING NO.

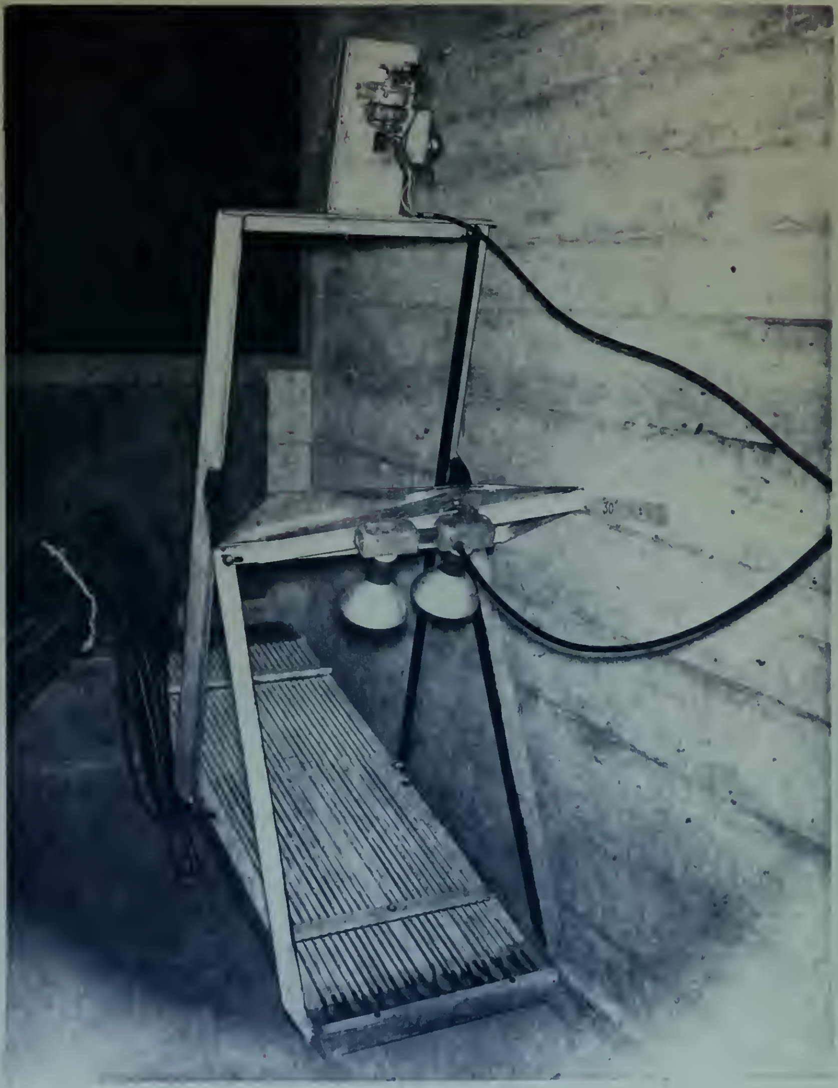


FIGURE 11

TILTING MULTIPLE MANOMETER
(in the 14.5° position)

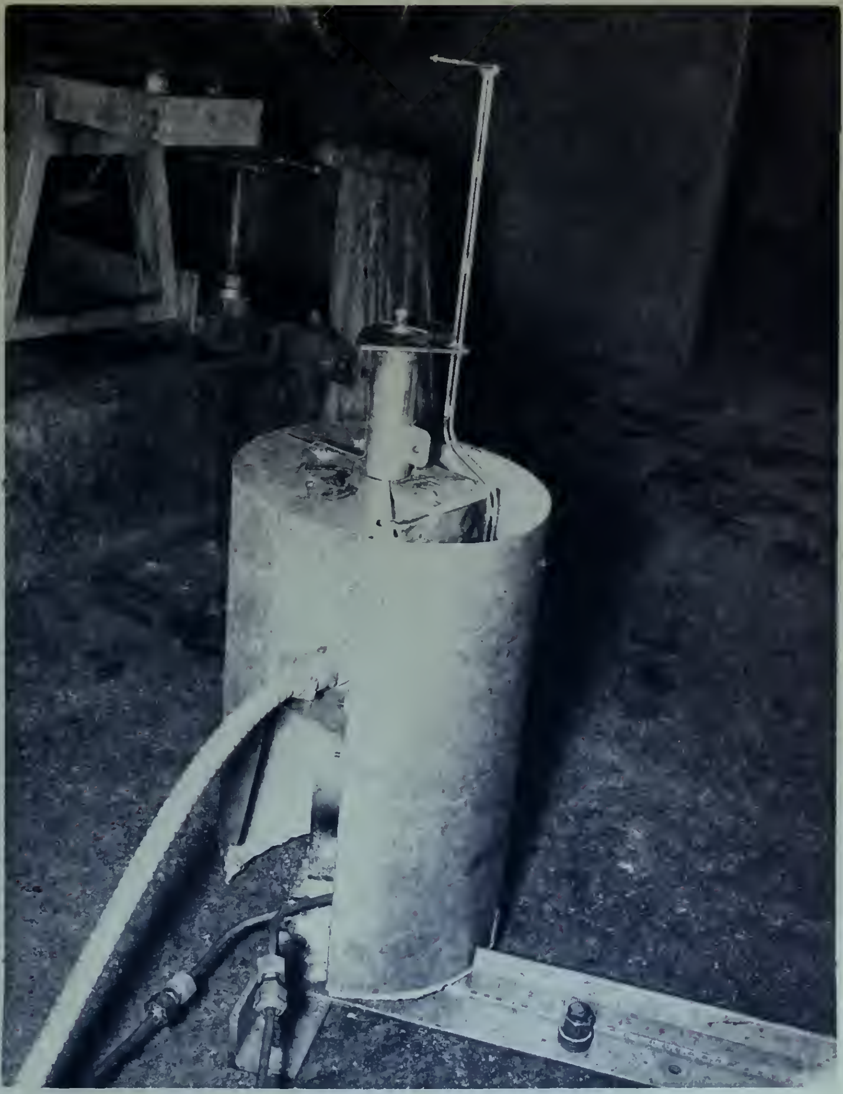


FIGURE 12

REMOTE CONTROLLED PITOT TUBE
(Assembled)

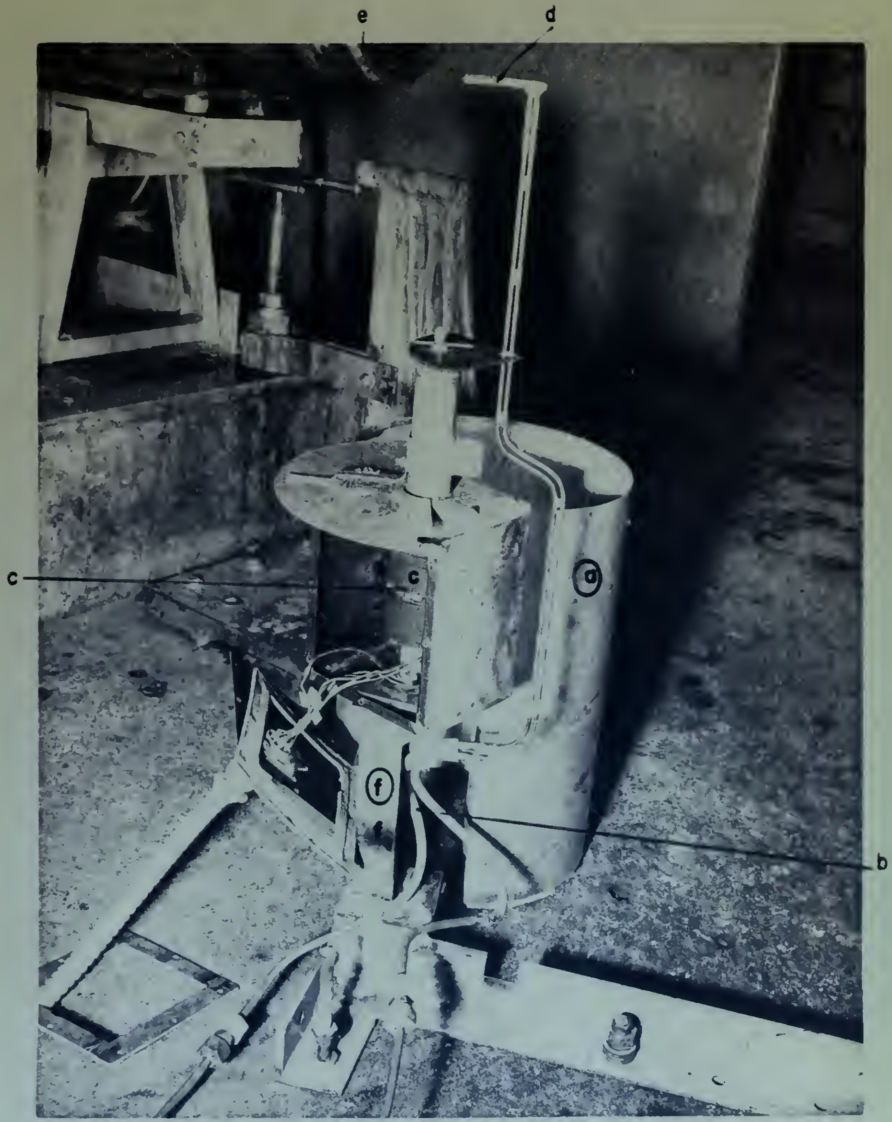


FIGURE 13

REMOTE CONTROLLED PITOT TUBE
(Disassembled)

(a) Aluminum shield
(b) Rubber tubes
(c) Synchro
(d) Pitot tube
(e) Motor
(f) Adjustable support

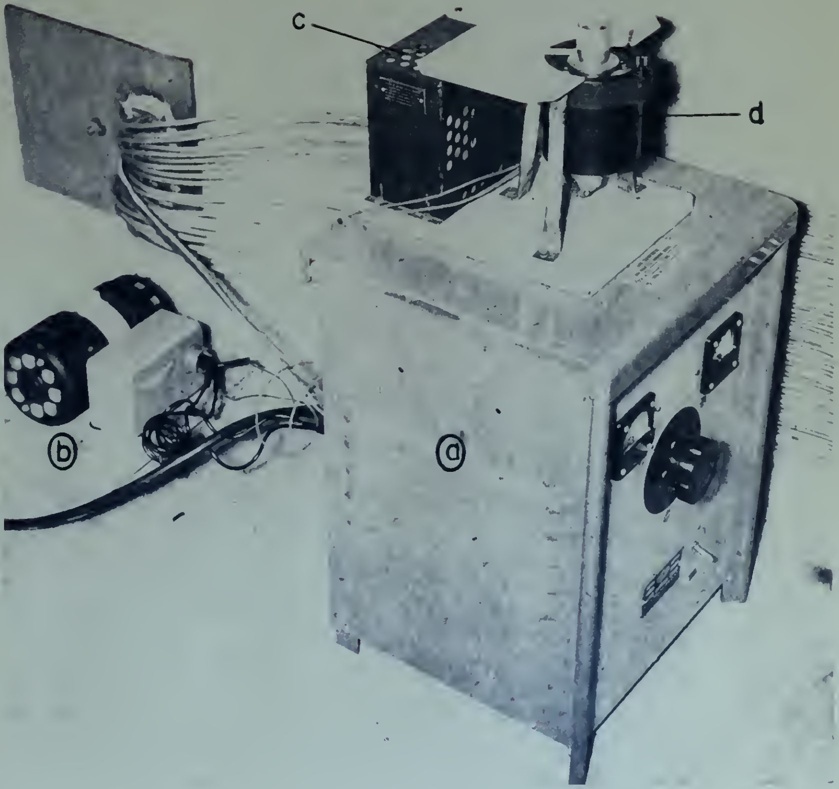


FIGURE 14

SYNCHRO CONTROL

a Rectifier (220 a.c. to 24 d.c.)
b Inverter (24 d.c. to 110 a.c. 400 ~)
c Amplifier
d Synchro

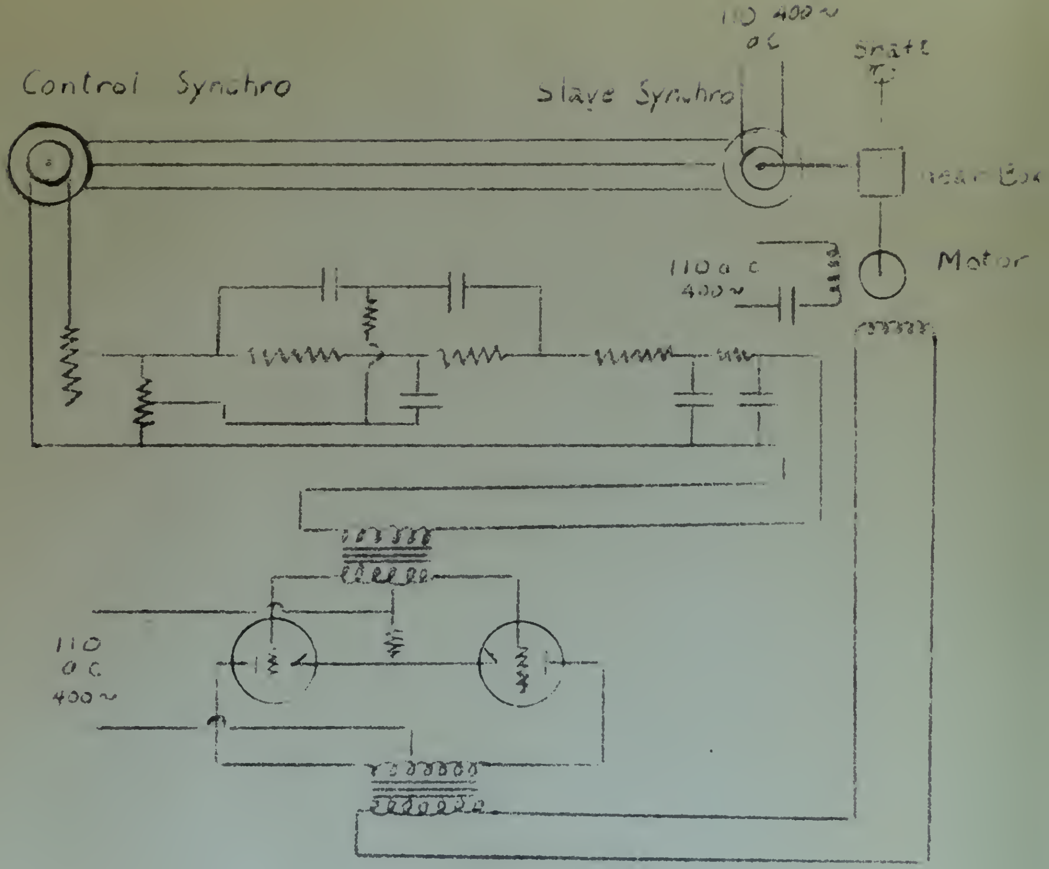


FIGURE 15

Electrical Circuit For The Remote Controlled Pitot-Static Tube

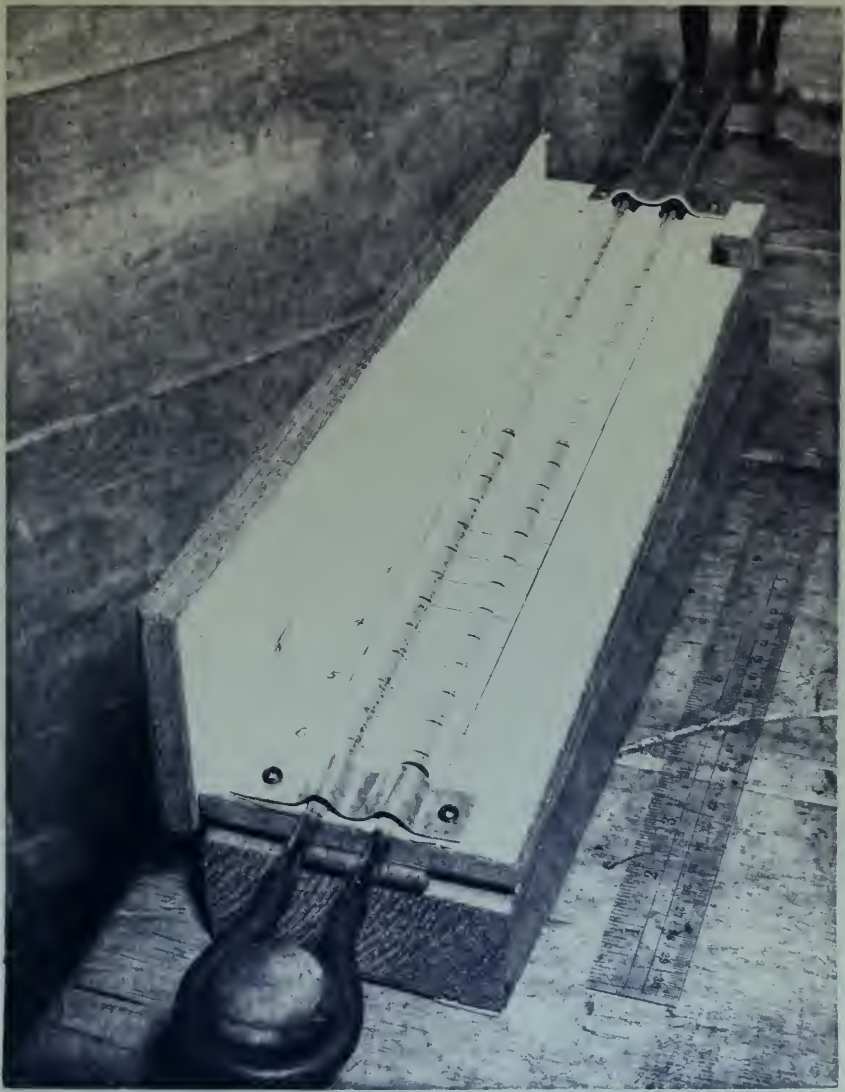


FIGURE 16

SMALL INCLINED MANOMETER

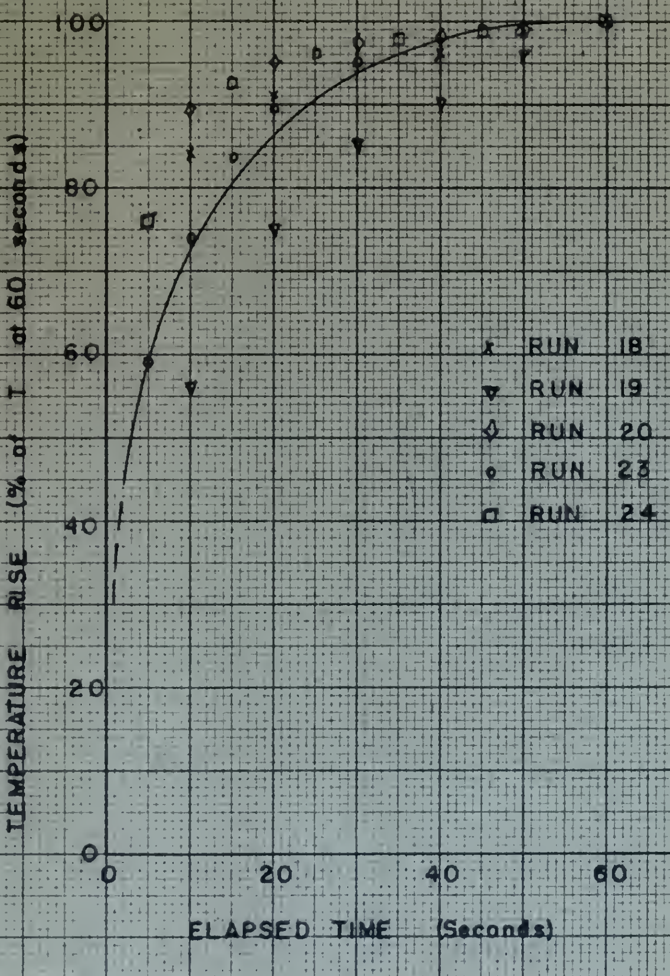


FIGURE 17

THERMOCOUPLE TEMPERATURE RESPONSE

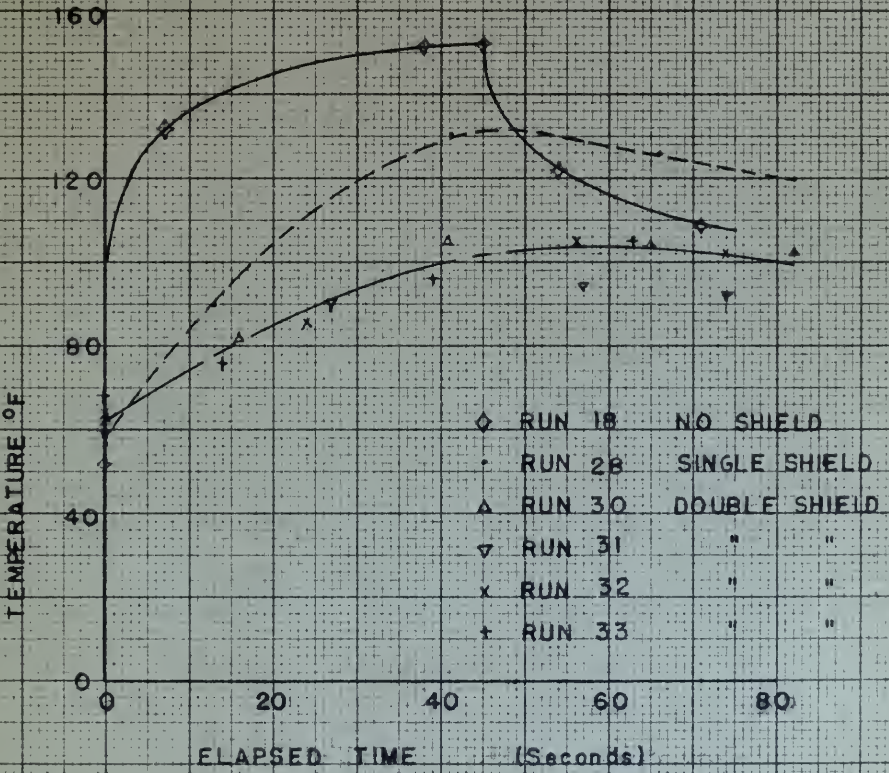


FIGURE 18

SHIELDED THERMOCOUPLE RESPONSE

DIETERICH-POST CO. NO. 148 20 DIVISIONS PER INCH BOTH WAYS 300 BY 200 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1000H

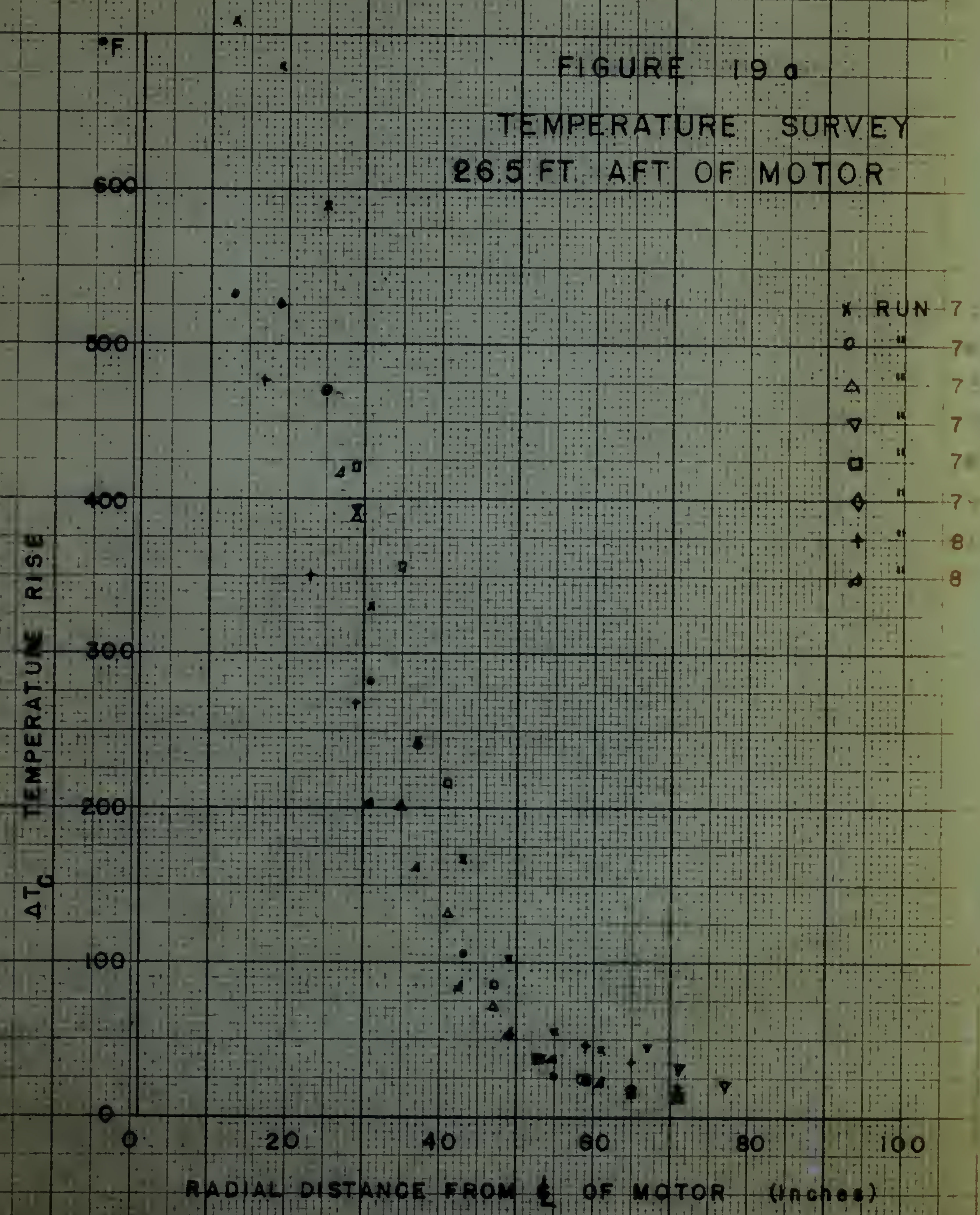


FIGURE 19a
TEMPERATURE SURVEY
26.5 FT. AFT OF MOTOR

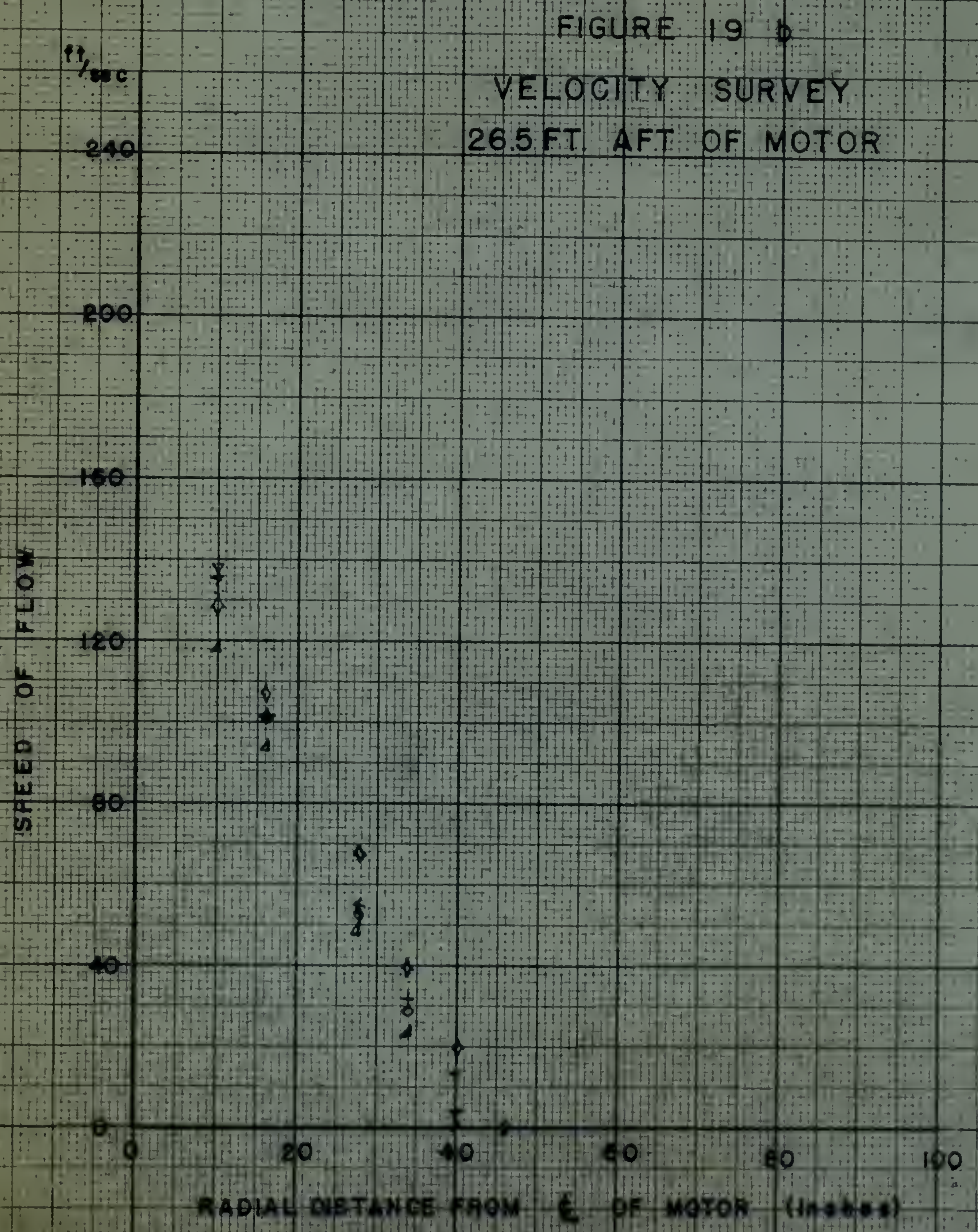


FIGURE 19b
VELOCITY SURVEY
26.5 FT. AFT OF MOTOR

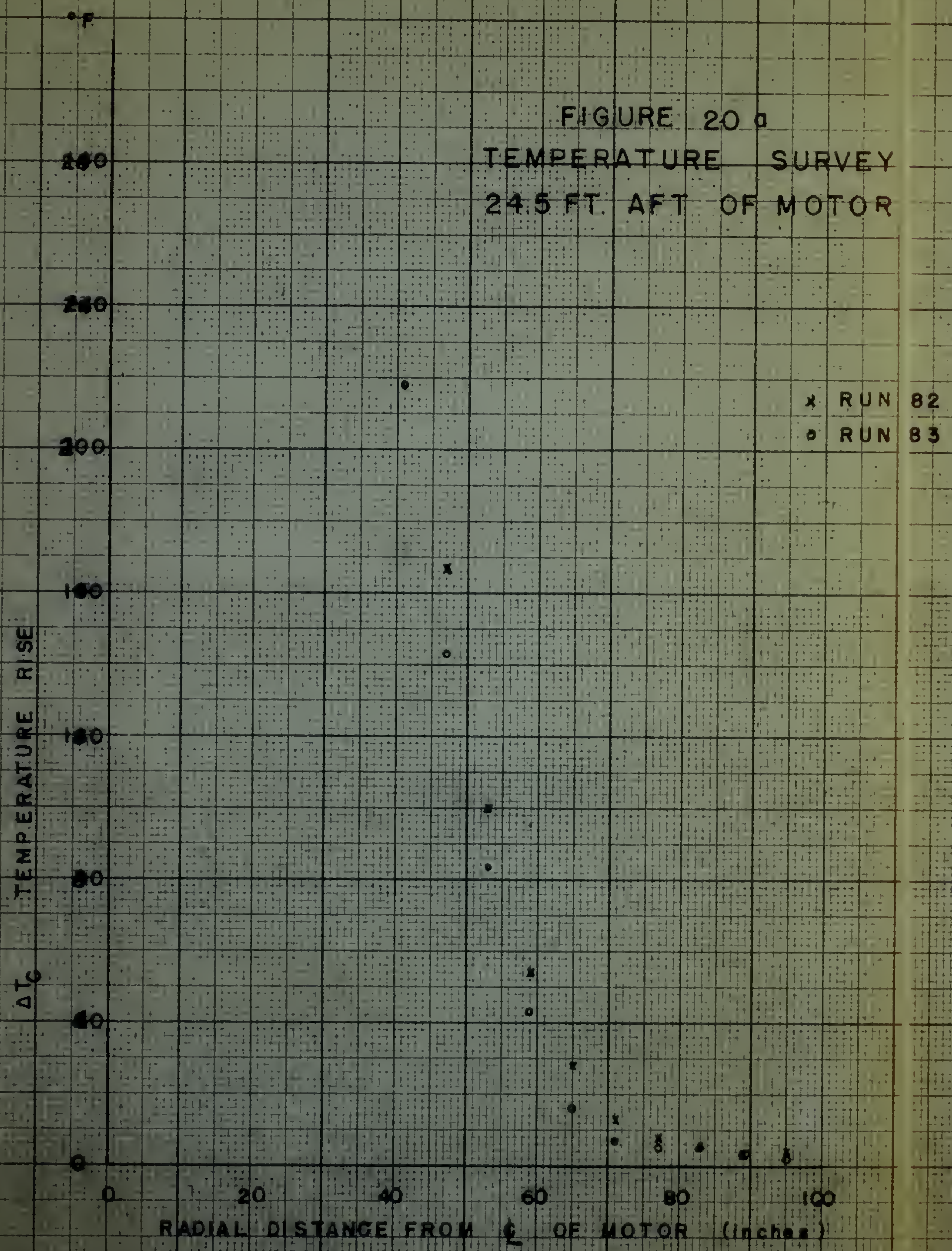


FIGURE 20 a
TEMPERATURE SURVEY
24.5 FT. AFT OF MOTOR

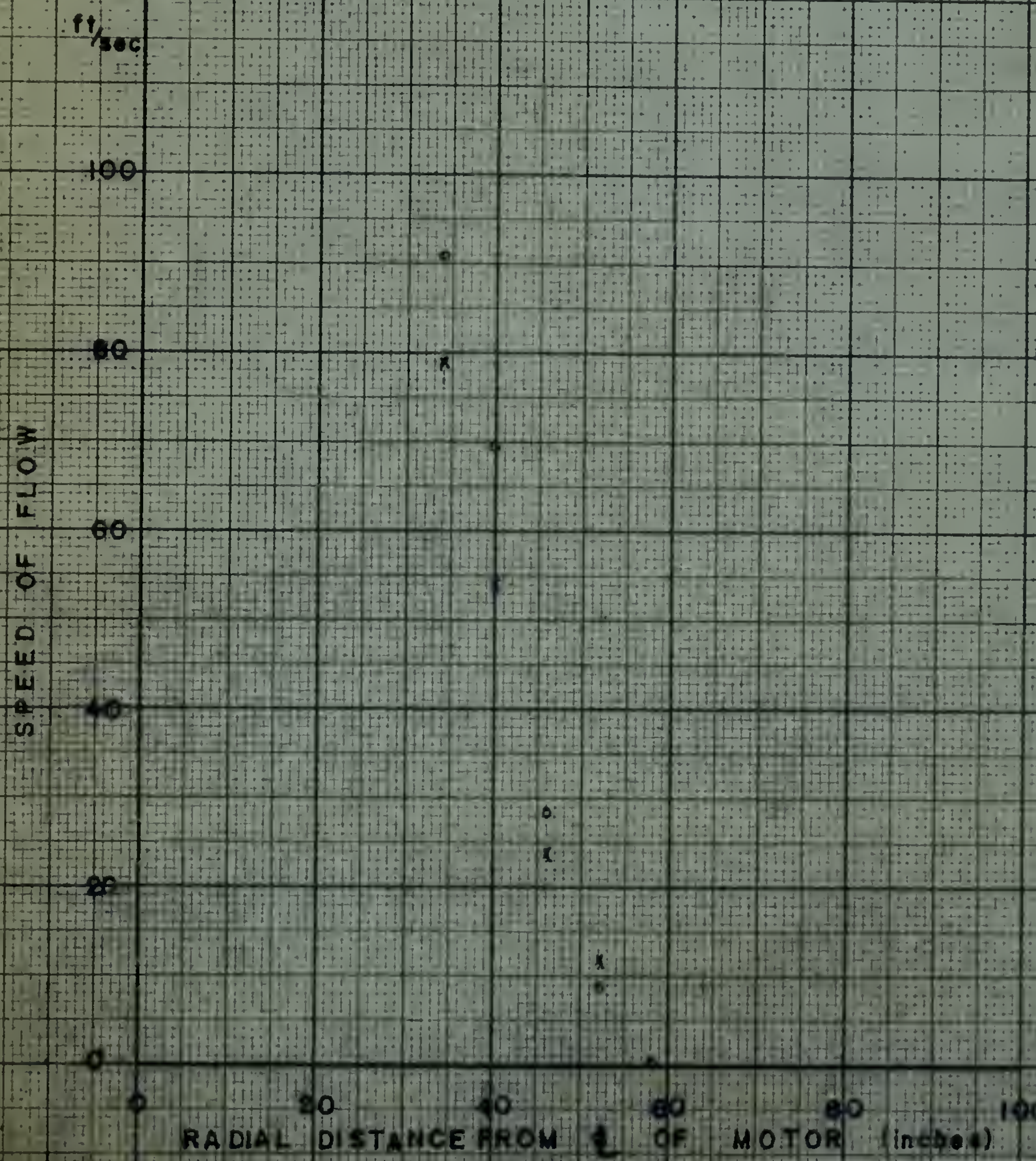


FIGURE 20b
VELOCITY SURVEY
24.5 FT. AFT OF MOTOR

DIETRICH-POST CO. NO 148 20 DIVISIONS PER INCH BOTH WAYS 100 BY 200 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO 1000H

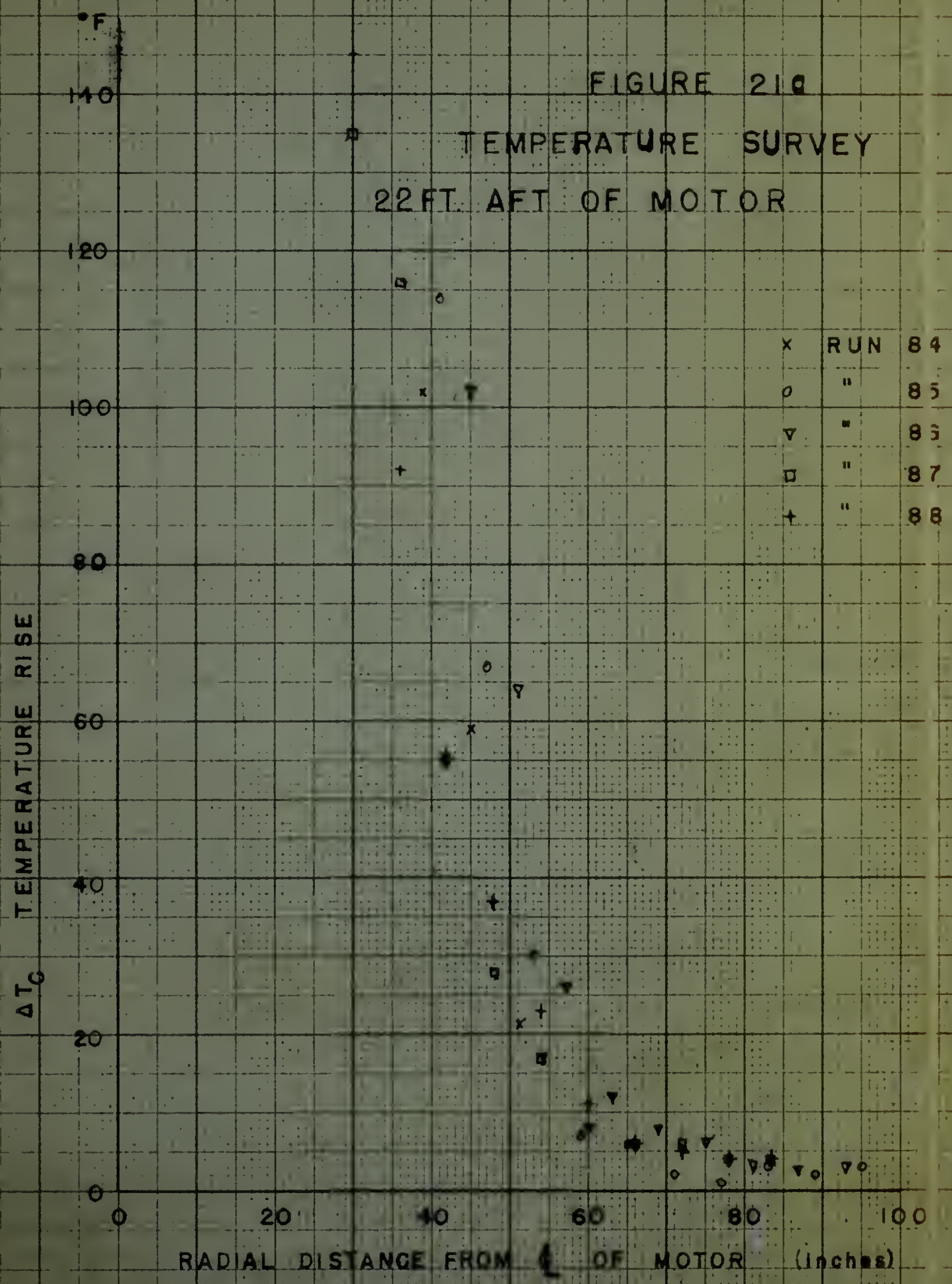


FIGURE 21a

TEMPERATURE SURVEY

22 FT. AFT OF MOTOR

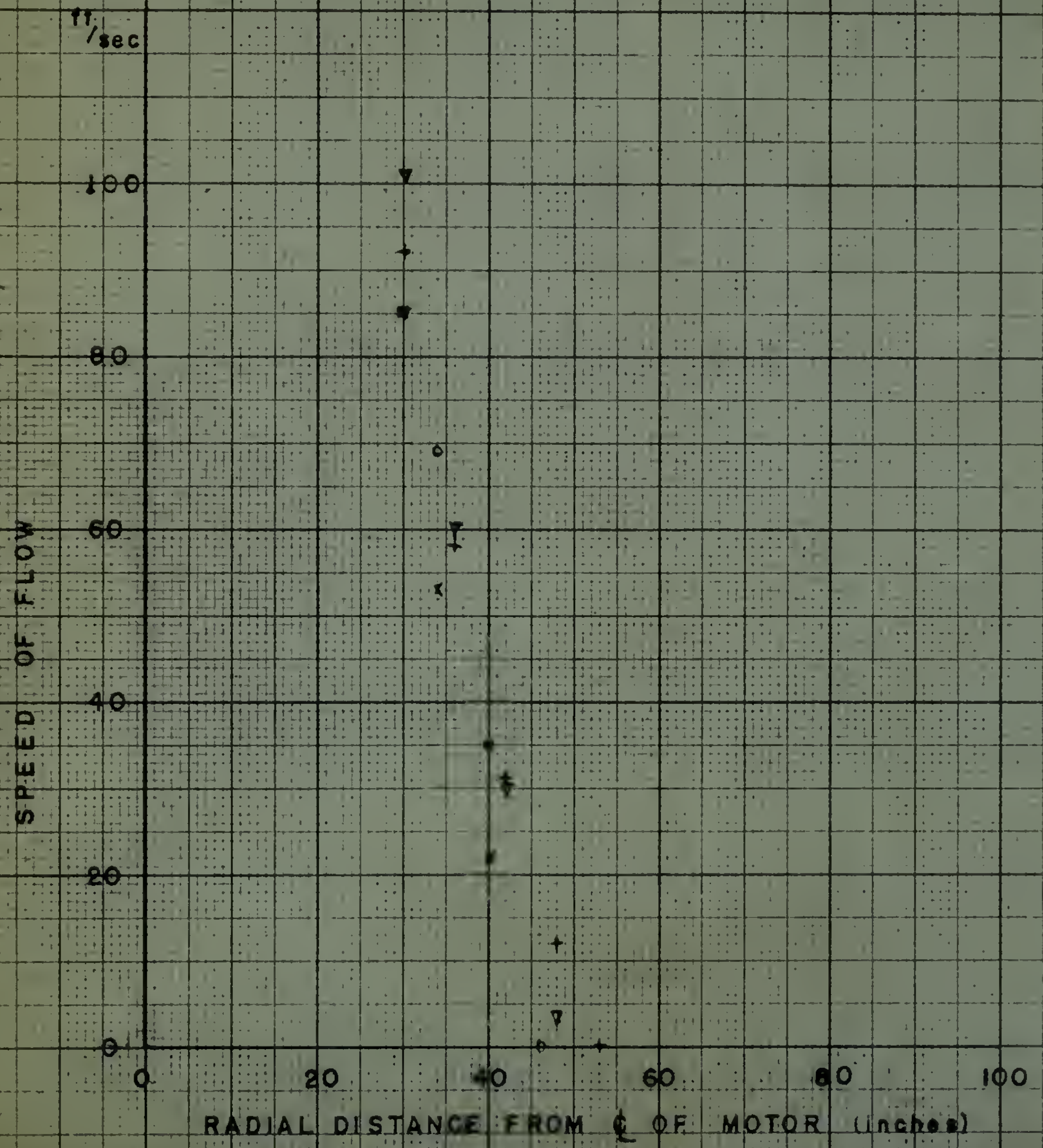


FIGURE 21 b

VELOCITY SURVEY

22 FT. AFT OF MOTOR

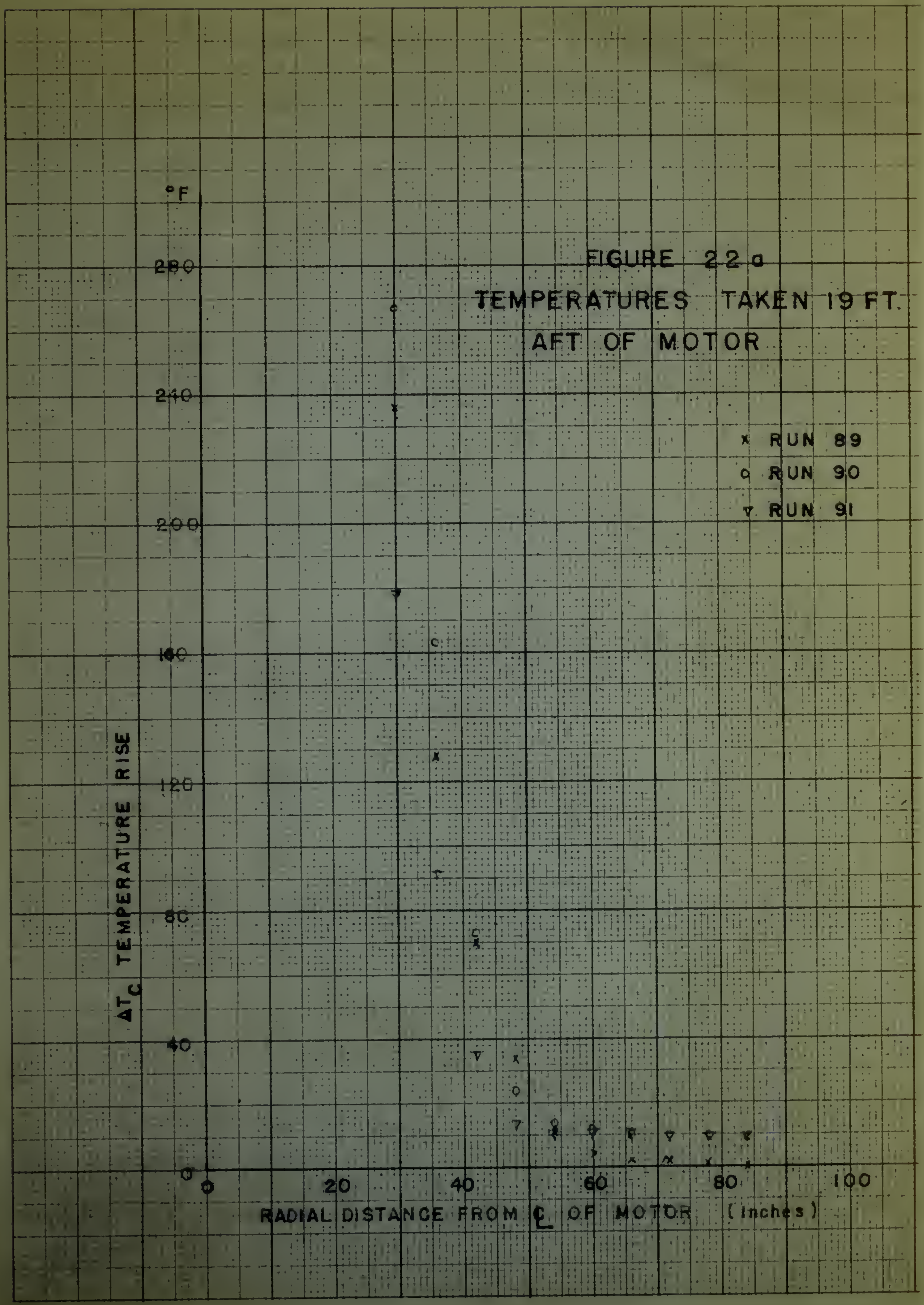


FIGURE 22a
TEMPERATURES TAKEN 19 FT. AFT OF MOTOR

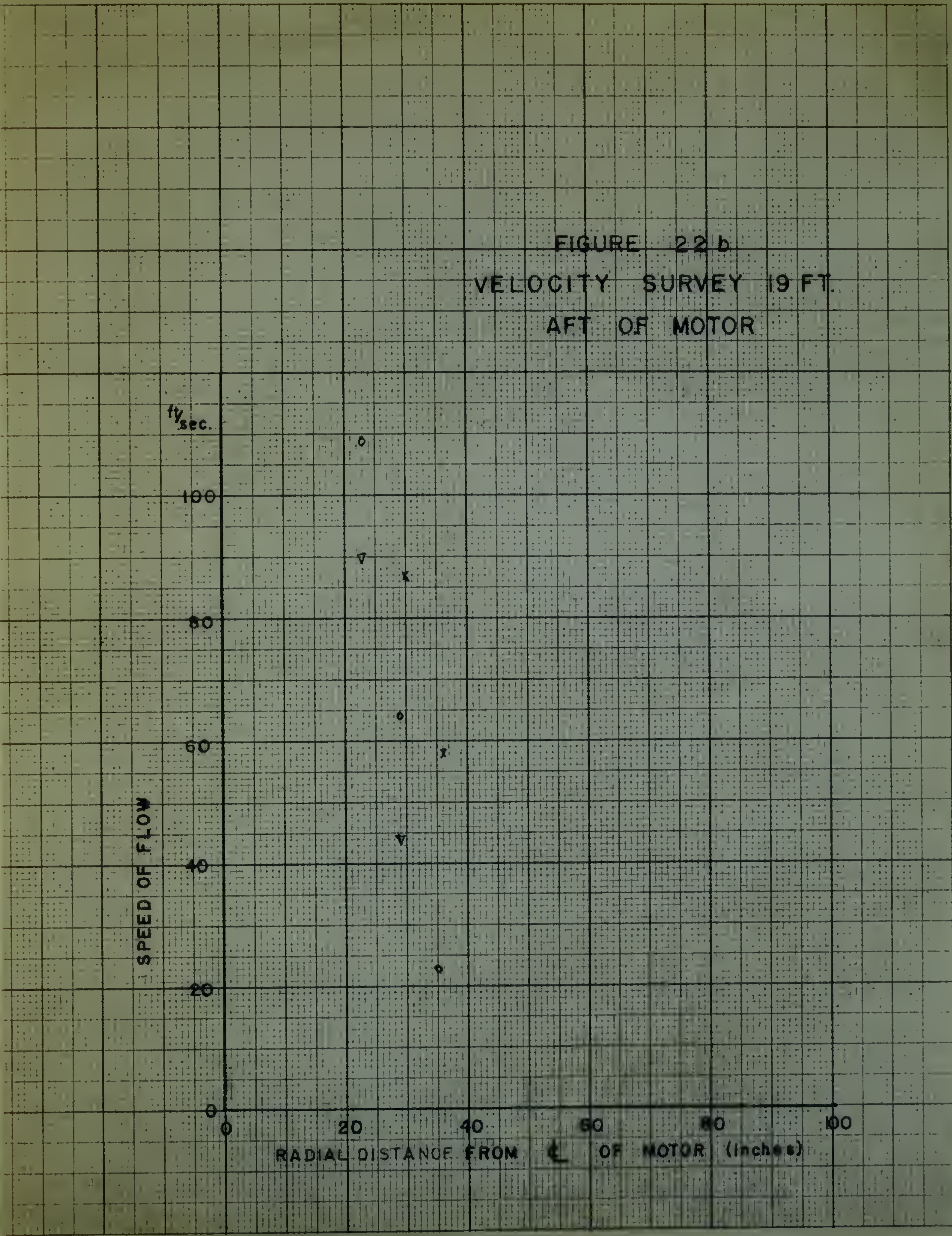


FIGURE 22b
VELOCITY SURVEY 19 FT. AFT OF MOTOR

DIETRICH-POST CO. No. 148 20 DIVISIONS PER INCH BOTH WAYS 100 BY 200 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1000H

FIGURE 23a
TEMPERATURES TAKEN 16 FT.
AFT OF MOTOR

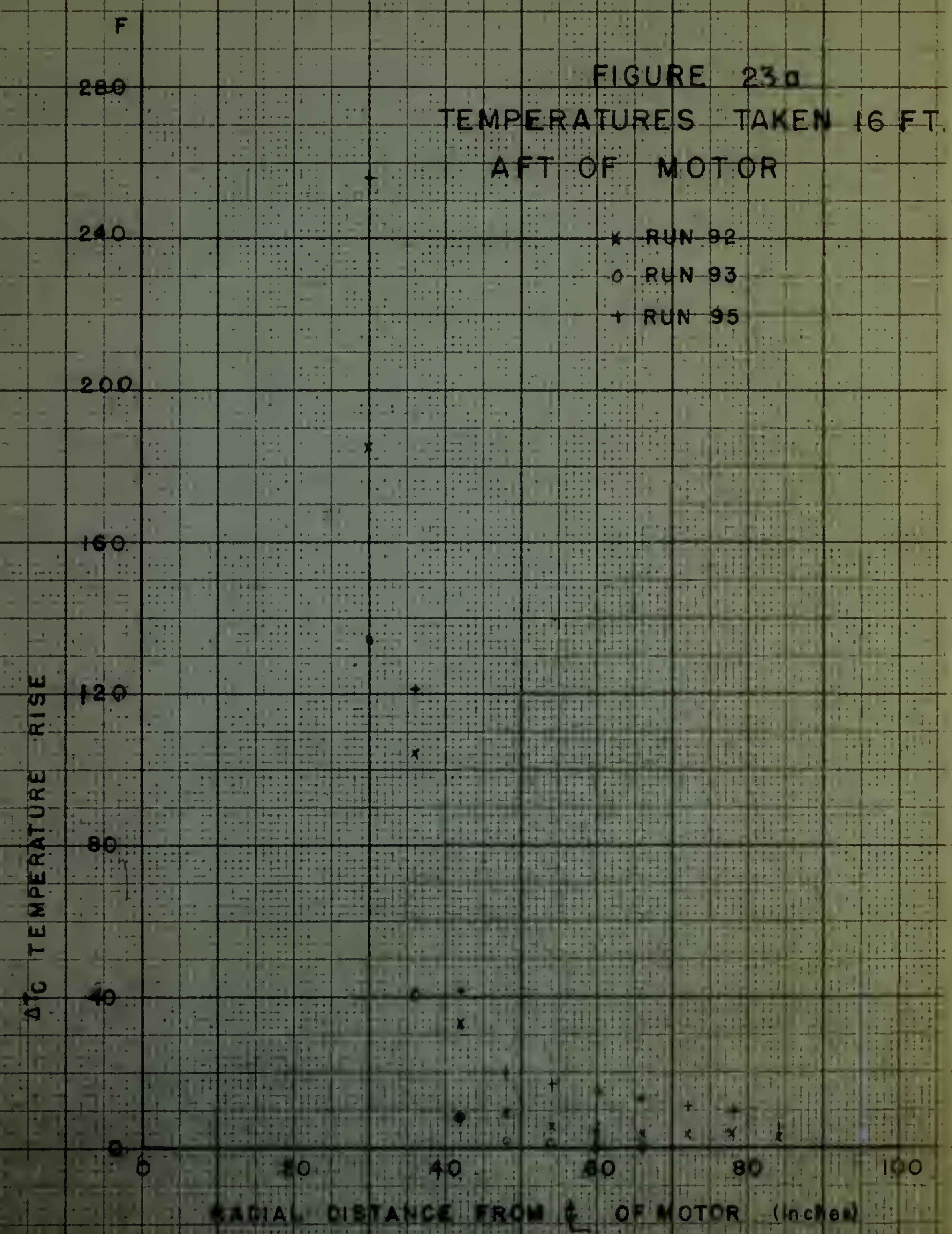
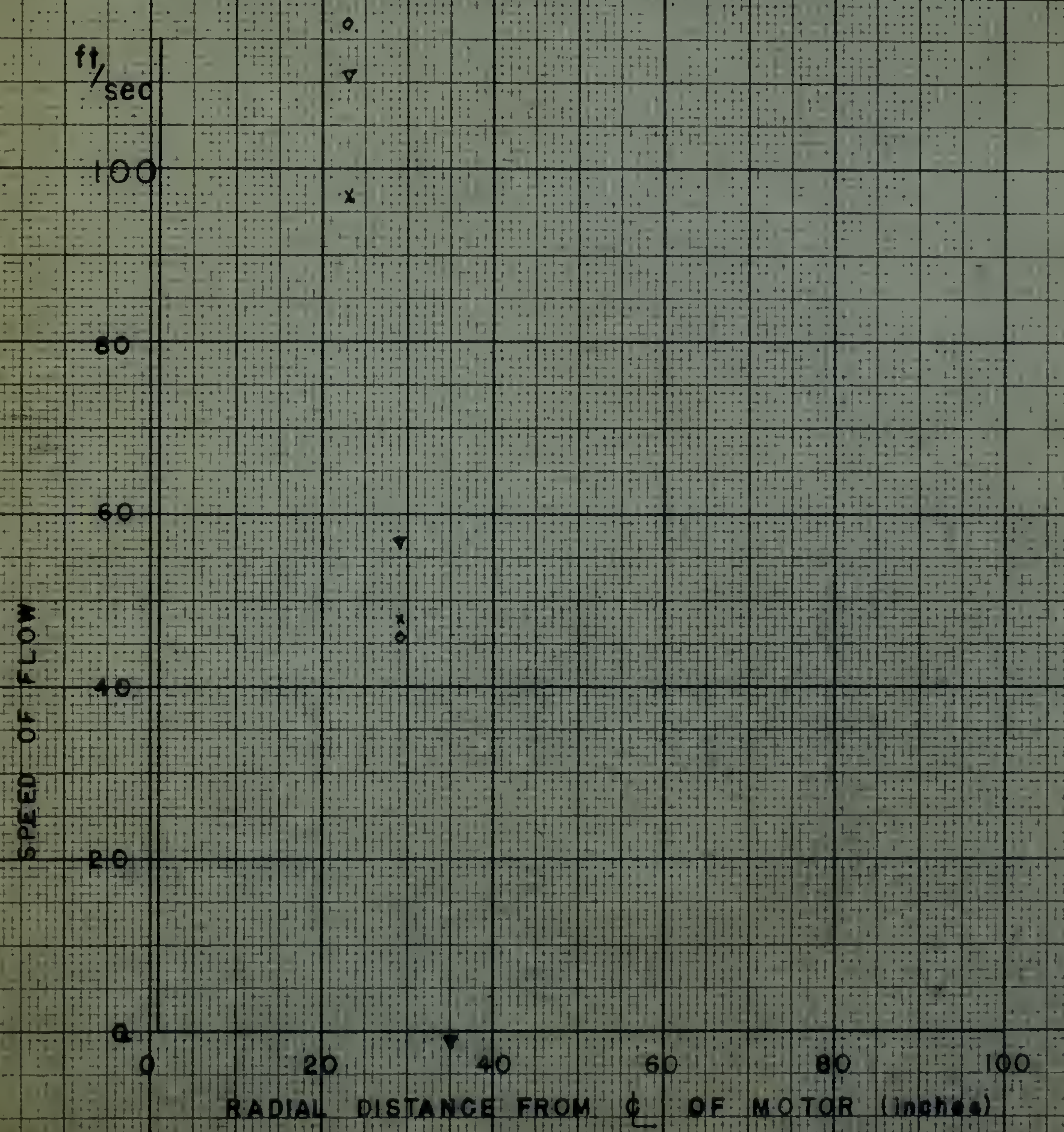


FIGURE 23 b
VELOCITY SURVEY
16 FT. AFT OF MOTOR



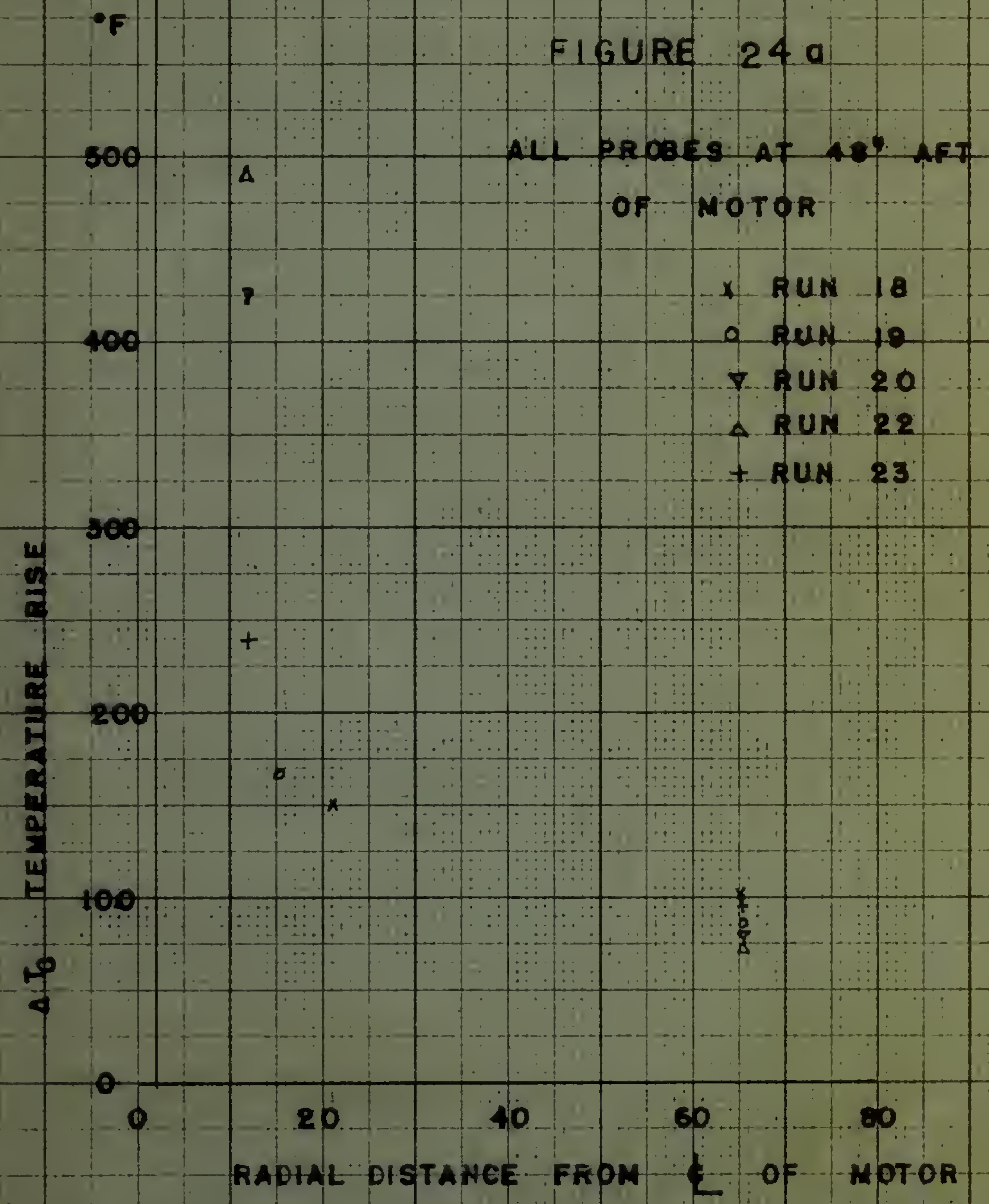


FIGURE 24 a

ALL PROBES AT 48" AFT OF MOTOR

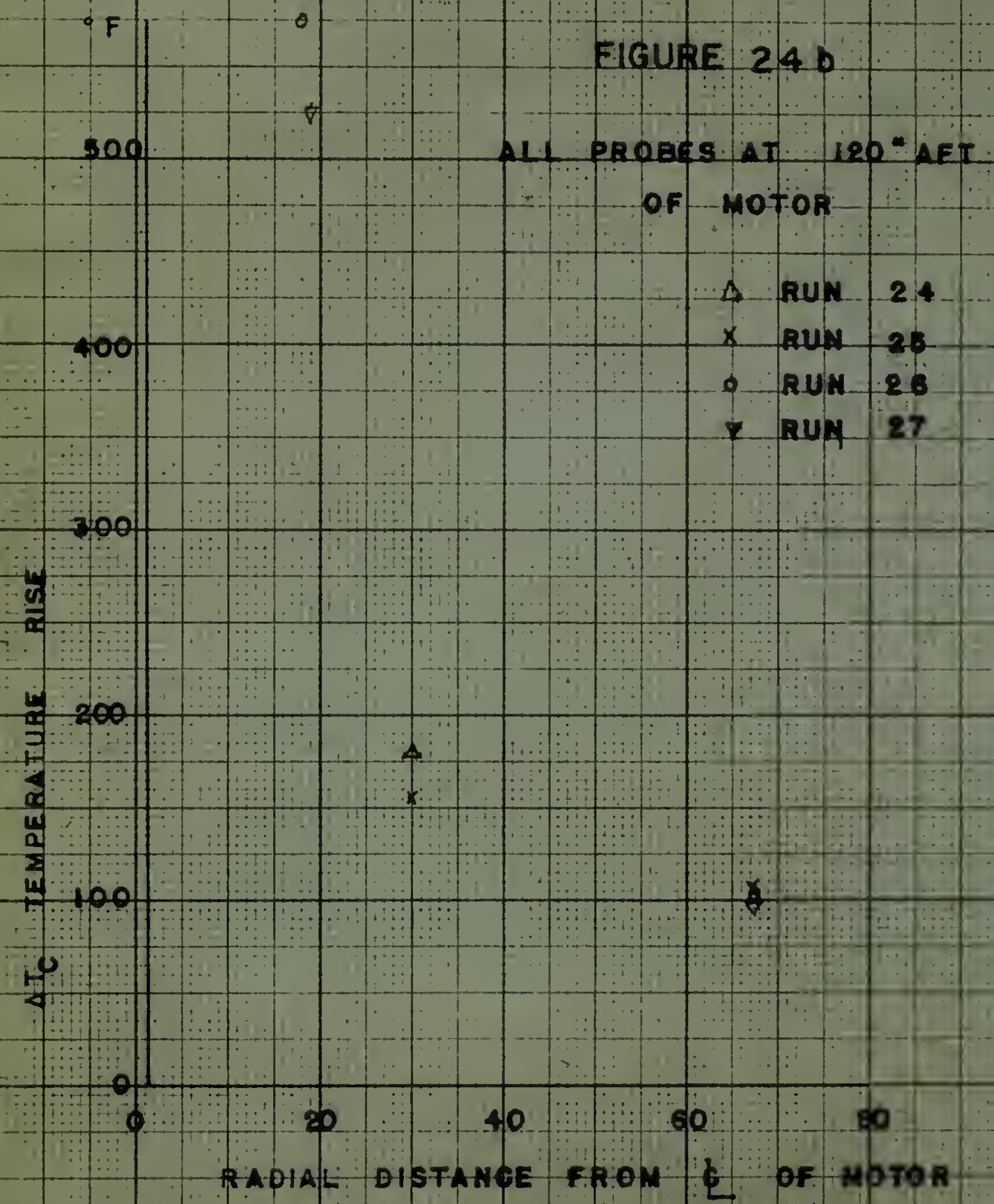


FIGURE 24 b

ALL PROBES AT 120" AFT OF MOTOR

## FIGURE 25

## VELOCITY SURVEY

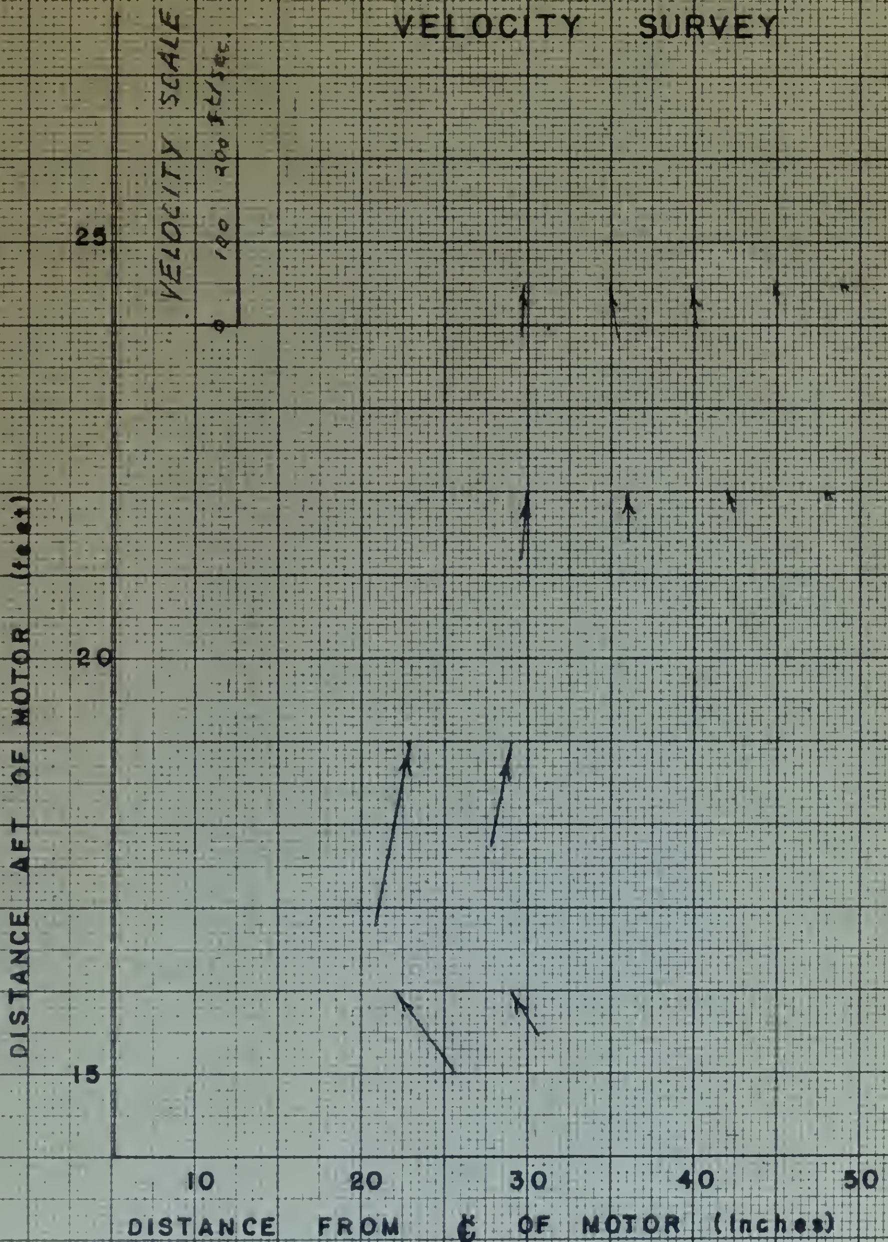
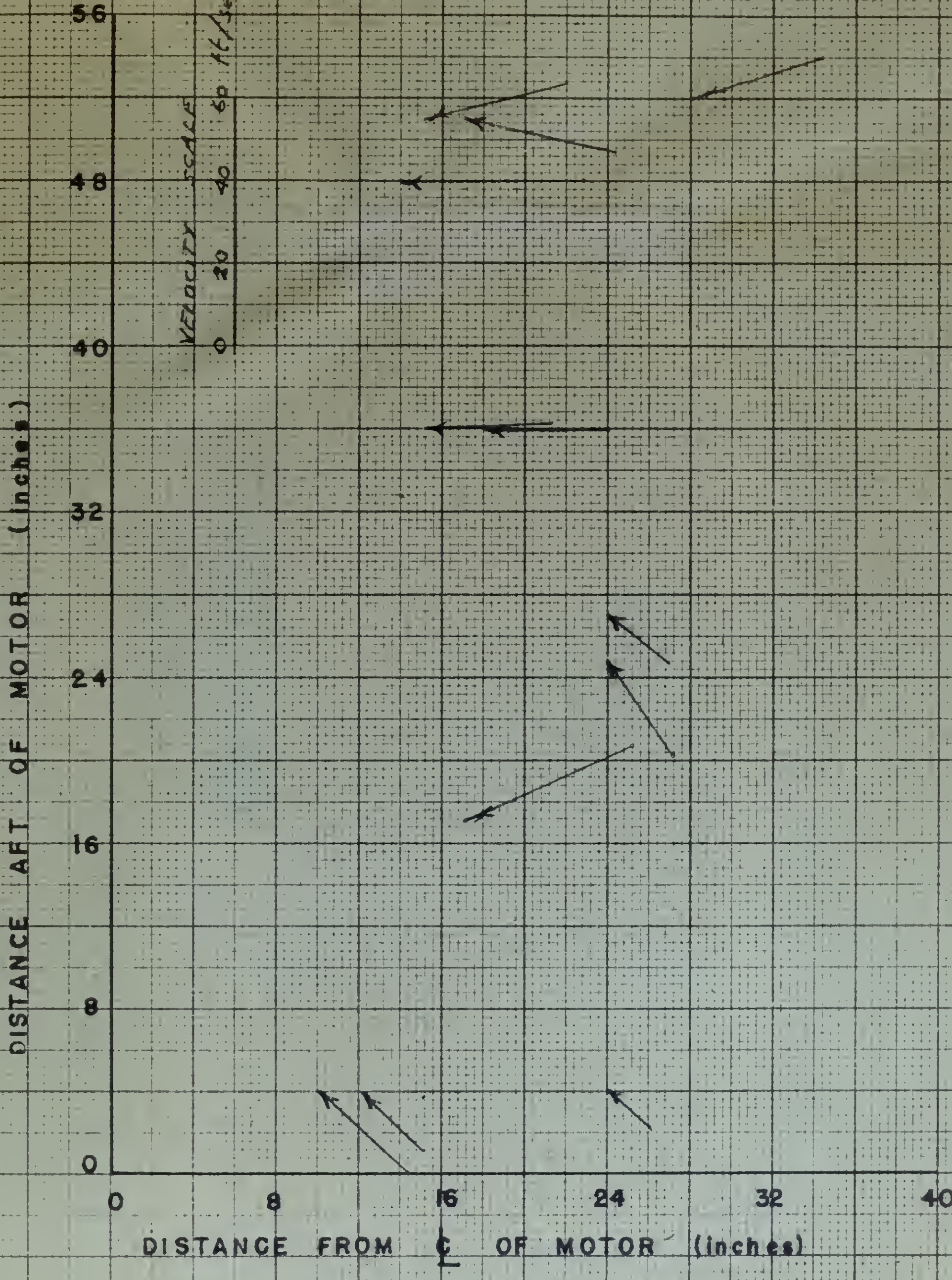


FIGURE 26

VELOCITY SURVEY



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